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Final Report to:

**U.S. Environmental Protection Agency**
**Region IX**

# Remedial Investigation Del Monte Corporation (Oahu Plantation) Superfund Site

## Kunia, Hawaii

## Volume I

Submitted by:

Golder Associates

Submitted for:

**Del Monte Fresh Produce (Hawaii) Inc.**

November 1998
963 1532.4000

3252-00272

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Golder Associates

# FINAL
# REMEDIAL INVESTIGATION REPORT
# VOLUME I

**For the**

**Del Monte Corporation**
**(Oahu Plantation) Superfund Site**

Prepared for:

Del Monte Fresh Produce (Hawaii), Inc.
Kunia, Hawaii

Submitted by:

Golder Associates Inc.
Redmond, Washington

November 6, 1998

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# EXECUTIVE SUMMARY

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This report, prepared by Golder Associates Inc. (Golder) for Del Monte Fresh Produce (Hawaii), Inc. (DMFP), presents the results of the Del Monte Corporation (Oahu Plantation) Superfund Site Remedial Investigation. In December 1994, the U. S. Environmental Protection Agency (EPA) placed the Del Monte Corporation (Oahu Plantation) site (the "Site") on the National Priorities List (NPL) pursuant to the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). In September 1995, DMFP on behalf of the Del Monte Corporation (DMC) and RJR Nabisco Holdings Company, signed an Administrative Order of Consent (AOC) with EPA and the State of Hawaii to conduct a Remedial Investigation and Feasibility Study (RI/FS) for the site. This RI report has been prepared in accordance with the AOC, the statutory requirements of CERCLA, and the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988).

## BACKGROUND

The Oahu Plantation is a 6,000 acre pineapple plantation currently owned and operated by Del Monte Fresh Produce (Hawaii), Incorporated (DMFP). The plantation is located on the north-central plateau of the Island of Oahu. The plateau is bounded to the west by the Waianae Mountain Range and on the east by the Koolau Mountain Range. The plantation has been used for cultivation of pineapple since the early 1940s. The DMFP facility is comprised primarily of agricultural areas but also contains two company operated housing complexes (Kunia Village and Poamoho Village), as well as equipment maintenance areas, pesticide storage facilities, warehouses, and administrative buildings.

From 1946 through April 1980, domestic and agricultural water was supplied to Kunia Village by the Kunia Well (State Well No. 2703-01). In the 1970s, the well served approximately 700 people.

In April 1977, an accidental spill involving approximately 495 gallons of the soil fumigant ethylene dibromide (EDB) possibly containing 0.25% 1,2-dibromo-3-chloropropane (DBCP) occurred on bare ground within approximately 60 ft of the Kunia Well. The accidental spill resulted from the failure of a defective hose on a bulk transport container owned by Dow Chemical Company (DOW) during transfer operations to an above ground storage tank. Photographic records from the Hawaii Department of Health (HDOH) indicated that the leading edge of the accidental spill reached the cement pad of the Kunia Well. EDB was not detected above a detection limit of 0.5 $\mu$g/L in the Kunia Well in testing conducted one week after the spill by the HDOH.

Subsequent sampling of the Kunia Well, conducted in 1980 by the HDOH did detect the presence of EDB and DBCP in the Kunia Well. Based on these results, the well was disconnected from the potable water system in April 1980. Drinking water for the Kunia Village and DMFP workplaces is currently supplied by the "Navy Well" (State Well No. 2803-05), and since 1991 after approval by HDOH, by Del Monte Well No. #4 (State Well No. 2803-07) located approximately 1.5 miles north of the Kunia Well site.

In response to the detection of the compounds in the Kunia Well, the owner/operator of the plantation at the time, Del Monte Corporation (DMC), in cooperation with the State Departments of Agriculture and Health, initiated soils and groundwater investigations, and remedial cleanup efforts in the vicinity of the Kunia Well. As a result of these activities, other areas impacted with fumigants near the well were identified in addition to the Kunia Well spill area, including the Former Fumigant Mixing Area and Former Fumigant Storage Area. These areas are located within about 50 to 150 ft north of the Kunia Well.

As a result of soil investigation results, soil removal was conducted during two phases of excavation activities. In 1981, approximately 2,000 tons of soil were removed from the Spill Area. Soil sampling conducted after completion of this phase of soil removal indicated elevated levels of EDB and DBCP remained. As a result, a further 16,000 tons of impacted soil were excavated from impacted areas in the fall of 1983. The excavation created a 60 feet deep by 75 feet wide by 75 feet long excavation. Soil removal was terminated when perched groundwater infiltrated the excavation. Excavated soils were placed in Field 8 to allow for volatilization and natural attenuation to occur. This was conducted with approval from the State of Hawaii.

A Preliminary Assessment/Site Inspection (PA/SI) was conducted at the site in 1990 by EPA. EPA subsequently completed a Hazard Ranking Scoring (HRS) process for the site in 1992 which led to a proposed listing on the NPL.

During 1994, a public health assessment was conducted by the Agency for Toxic Substances and Disease Registry (ATSDR) pursuant to requirements mandated by the proposed listing on the NPL. The ATSDR studied the historical data for the site, including the pre-1980 use of the Kunia Well as a drinking water source. The ATSDR's study also included the previous response activities conducted at the site (i.e., use of water from the Kunia Well for irrigation of non-crop areas and use of water from perched wells for dust control on in-field pineapple roads). In a report dated February 7, 1995, ATSDR concluded that residents of Kunia Village had not been exposed to significant levels of EDB and DBCP in their drinking water, and the Oahu Plantation was classified as a "No Apparent Public Health Hazard" for past and current conditions (ATSDR 1995). It is not anticipated, according to ATSDR, that Kunia Village residents who utilized the Kunia Well as their drinking water source will have any adverse health effects. ATSDR also concluded that the site may pose an "Indeterminate Health Risk," however, for future exposures due to the need to characterize potential impacts on downgradient wells.

The site was added to the NPL on December 16, 1994, and an AOC for an RI/FS and Engineering Evaluation and Cost Analysis (EE/CA) was signed by DMFP and EPA on September 28, 1995. EPA and DMFP agreed on January 23, 1997 to include the soils operable unit in the FS rather than in a separate EE/CA to more effectively complete the remedial evaluation process by considering interactions of soils and groundwater. The AOC SOW developed by EPA and the State describes the investigative work at the Kunia Village Area and Other Potential Source Areas required to meet the RI/FS objectives.

The objective of the Del Monte Corporation (Oahu Plantation) Superfund Site Remedial Investigation (RI) is to gather and develop the necessary information to assess the nature and extent of chemicals of potential concern (COPCs) in soils and/or groundwater at the known and suspected source areas that have been identified in association with the site. The data has been collected to support: 1) an assessment of potential risk to human health and the environment, 2) a determination of the need for further remediation at the site to address any unacceptable risks, and 3) identification, evaluation and selection of remedial alternatives required to meet the site-specific Remedial Action Objectives (RAOs).

## REMEDIAL INVESTIGATION

The overall goal of the RI field sampling activities was to estimate the nature and extent of impacts from chemicals of potential concern (COPCs) at known and suspected source areas, and to characterize the chemicals present in sufficient detail to prepare a Baseline Risk Assessment (BRA) and Feasibility Study (FS). Data required to support these goals include information on geology, hydrogeology, soils, surface water and sediments, and the nature and extent of chemicals throughout pertinent environmental media. The rationale and approach for site field investigations were evaluated in the *Work Plan for Remedial Investigation and Feasibility Study at the Del Monte Corporation (Oahu Plantation) Superfund Site* (ICF 1997).

The Work Plan identified the following "known" sources (where chemicals have been observed) which are collectively referred to as the Kunia Village Area:

- Kunia Well Spill Area;
- Former Fumigant Storage Area; and
- Former Fumigant Mixing Area.

Additionally, suspected sources of potentially hazardous chemicals (Other Potential Source Areas) were selected by EPA based upon a review of historical activities at the Oahu Plantation. Releases of potential hazardous chemicals were not known to have occurred at these areas. The other potential source areas investigated during the RI include:

- Perimeter Areas of the Former Fumigant Storage and Mixing Areas;
- Former Fumigant Storage Area near Field 32;
- Empty Former Fumigant Drum Burial sites;
- Former Underground Storage Tank (USTs) sites;
- Methyl Bromide Cylinder Burial Site in Field 71; and
- Current Soil Fumigant Storage Facility.

Although not identified as an Other Potential Source Area in the RI/FS Work Plan, the Excavation Pit Soils Natural Attenuation Area in Field 8 was also investigated during the

RI at the request of EPA. These known and suspected source areas were investigated under the following media-specific groupings:

- **Soils Operable Unit.** The soils operable unit includes surface and vadose zone soils in the Kunia Village Area, as well as soils associated with the Other Potential Source Areas;
- **Surface Water and Sediment.** Surface water and sediments are associated with the ephemeral stream gulch northeast of the Kunia Village Area, the smaller ravine southeast of the Kunia Village Area, and the associated run-off pathways; and
- **Groundwater Operable Unit.** The groundwater operable unit consists of the perched groundwater zone and basal aquifer in the Kunia Village Area.

The rationale and approach for field sampling in each of these areas were evaluated in the Work Plan using the Data Quality Objective (DQO) process as detailed in EPA guidance (EPA 1993). DQOs are used to develop a scientific and resource-effective sampling design, and are established through a process that is designed to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended application. The DQO process was applied in the Work Plan to provide the rationale for sampling to support the objectives of the remedial investigation.

The DQOs were applied quantitatively to the soil sampling program for the known source areas (Former Fumigant Storage Area, Former Fumigant Mixing Area and the Kunia Well Spill Area). A qualitative or subjective sampling approach was used to design the sampling of soils for the other potential source areas to assess if COPCs exist which pose an unacceptable health exposure or environmental risk. The judgmental sampling approach was applied in the other potential source areas because it is considered most appropriate and efficient for satisfying the specific field investigation objectives detailed in the Work Plan. Details of the field investigation procedures necessary to implement the Work Plan were subsequently presented in the *Field Sampling Plan for Remedial Investigation and Feasibility Study at the Del Monte Corporation (Oahu Plantation) Superfund Site* (Golder 1996a). The support project plans include: Health and Safety Plan (HSP), and Quality Assurance Project Plan (QAPP) (Golder 1996b,c).

## DATA COLLECTION ACTIVITIES

The following is a summary of data collection activities completed in each of the study areas investigated as part of this RI.

**Kunia Village Area Soil Sampling** - A total of 45 boreholes were drilled and sampled throughout the Kunia Village Area. Soil boring and sample collection for chemical analysis was conducted using a Strataprobe direct push technology drilling system or using a hand driven core sampler. A total of 159 soil samples were collected from the 45 boreholes. Soil samples in the near-surface zone were collected at depths of 0.5, 2, and 5 feet below ground surface. For subsurface soils above the perched water table (vadose

zone soils), samples were collected at depths of 0.5, 2, 5, 10, 15 and 25 feet or until the perched aquifer was intercepted. Soil samples in the former Fumigant Mixing Area were collected at depths of 1 and 3 feet below ground surface.

All soil samples were analyzed for Volatile Organic Compounds (VOCs) by EPA Method 8260 (which included EDB and DBCP compounds). A subset of 10% (20% in the Former Fumigant Storage Areas) of these samples were also analyzed for the full COPC list of compounds which includes: VOCs (EPA Method 8260), TPH-diesel (EPA Method 8015M), lindane, toxaphene, and heptachlor (EPA Method 8080), bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141). Both soil and water samples collected prior to February of 1998 were analyzed by Ceimic Corporation located in San Diego, California. Ceimic closed their San Diego laboratory in February, 1998, after which the contract laboratory for the project was changed to Sequoia Analytical in Petaluma, California who subcontracted Methods 619, 632 and 8141 analyses to North Coast Laboratory in Arcata, California. Contract laboratories were audited by Golder Associate's chemist and approved for use during the Remedial Investigation by EPA.

Soil samples were collected for analysis of physical parameters during drilling of monitoring wells MW-1, MW-2 and MW-3. Soil sampling for physical parameters was conducted using a Mobile Drill B-61 auger drilling rig and 2-inch diameter split spoon sampler lined with brass sleeves. Samples were collected from approximate depths of 2, 5, 10, 25, and 35 feet bgs. Soil physical parameters included bulk density, specific gravity, organic matter content, grain size distribution including hydrometer testing, porosity, and water content. In addition, Shelby tube samples were collected in the saturated zone of the three monitoring well boreholes for vertical permeability measurements. Physical testing was performed by Golder Associates Inc.'s geotechnical laboratory in Redmond, Washington.

Additional soil samples were collected from nine boreholes drilled in the Former Fumigant Storage Area of the Kunia Village Area. The nine boreholes were drilled to further characterize the extent of COPCs detected in deeper soils (i.e. below 30 ft depth) during drilling of monitoring wells MW-3 and MW-3s. The boreholes also provided data for the design and location of perched groundwater extraction wells associated with the phytoremediation Treatability Investigation (TI) being conducted by DMFP. Soil samples were collected at ten-foot depth intervals from each borehole starting at depth of 25 to 30 feet bgs and continuing until encountering weathered basalt or auger refusal. The sampling frequency was increased to every five feet in areas where potentially higher concentrations of COPCs were anticipated. All soil samples collected during TI borehole drilling were analyzed for volatile organic compounds by EPA Method 8260.

In order to evaluate chemical concentrations present in the soil air space, soil vapor sampling was conducted at a depth of 11 feet bgs in two boreholes located in the Former Fumigant Storage Area and two boreholes in the Kunia Well Spill Area. These boreholes were selected for soil vapor sampling because they were located in the area where elevated EDB and DBCP compounds were historically observed in subsurface soils. Soil vapor samples were obtained using the Strataprobe soil vapor sampling procedures as

referenced in the FSP (Golder 1996a) including use of a six liter Summa canister. Soil vapor samples were analyzed for VOCs by EPA Method TO14, at Air Toxics Ltd., Folsom, California.

EPA's oversight consultant, ICF Kaiser, collected two soil vapor samples in November 1997. One sample was collected in the Kunia Spill Area near a location where a soil vapor sample had been collected by Golder. The other sample was collected in the Former Fumigant Storage Area. Samples were collected using similar procedures as used by Golder. Analysis was performed at Environmental Analytical Service, Inc. located in San Luis Obispo, California.

**Kunia Village Area Surface Water and Sediment Sampling** - The surface water and sediments sampling was conducted in the ephemeral gulch northeast of the Kunia Village Area which eventually drains into the Poliwai Gulch, and the smaller ravine just to the southeast of the Kunia Village Area. The focus of the surface water and sediment investigation was to determine if potential residual contamination from stormwater runoff and eroded soils are present in the ravine and gulch sediment/soil or surface water at concentrations that pose an unacceptable risk to human health via exposure pathways defined in the Work Plan.

The sampling conducted to meet the Work Plan objectives included the collection of five sediment samples along the northeast ephemeral gulch, three soil samples within the ravine southeast of the Kunia Spill Area, and two surface/near surface sampling locations in areas downgradient of both the Kunia Well Spill Area and the Former Fumigant Storage Area. Surface water samples were collected from three locations along the flowpath of the ephemeral gulch northeast of the Former Fumigant Mixing and Former Fumigant Storage Areas during a period of heavy rainfall. One surface water sample was also collected from the pit water contained within the fenced area of the Former Fumigant Mixing Area.

Sediment samples were analyzed for VOCs including EDB and DBCP (EPA Method 8260). A subset of 10% of these samples were also analyzed for TPH-diesel (EPA Method 8015M), lindane, toxaphene, and heptachlor (EPA Method 8080), bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141). All surface water samples were analyzed for VOCs (EPA Method 8260), TPH-diesel (EPA Method 8015M), lindane, toxaphene, and heptachlor (EPA Method 8080), PAHs (EPA Method 8310) and EDB/DBCP (EPA Method 504.1). Analysis for bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141) were conducted on a single surface water sample (SW-2) selected in the field at a location most likely to receive runoff from the Kunia Village Area.

**Kunia Village Area Perched Groundwater** - EDB and DBCP have historically been detected above their respective MCLs in the perched water-bearing zone in the vicinity of the Kunia Village Area. The primary concern related to the residual COPCs is whether they pose an unacceptable risk to human health via the exposure pathways defined in the Work Plan, including:

- Transport of COPCs to either surface water via seeps or springs, or transport to the basal groundwater by migration through the unsaturated basalt or through the Kunia Well; and
- Ingestion, dermal contact or inhalation resulting from potential surfacing of perched groundwater in the area.

Data collected to address these issues for the perched zone aquifer included measurements of COPC concentrations to assess the lateral and vertical distribution of chemicals in the perched water-bearing zone and measurements needed to assess the hydraulic characteristics and hydrogeology of the perched water-bearing zone including permeability, groundwater flow direction and gradient.

In order to provide these data the following methods of data collection were used:

- Piezometer Installation - Using the Strataprobe drilling method, eight 1-inch diameter piezometers were installed within the upper portions of the perched water-bearing zone within the Kunia Village Area. Piezometers were installed in areas selected in the Work Plan necessary to meet the data collection objectives. Data collected from the piezometers through groundwater sampling and hydraulic testing were used to define the boundaries of the perched water-bearing zone, hydraulic properties of the perched groundwater system, and the lateral extent of VOCs (Method 8260), and EDB and DBCP (Method 504).
- Perched Groundwater Monitoring Well Installation - The Work Plan and FSP describe a judgmental sampling approach to optimally design the perched groundwater monitoring program in the Kunia Village Area. In accordance with this approach, three perched zone monitoring wells (MW-1, MW-2, and MW-3) were installed in the Kunia Village Area during an initial phase of field work. The vertical distribution of COPCs within the perched groundwater system was assessed during drilling the three initial monitoring wells using a Hydropunch groundwater sampling device. An initial round of groundwater samples were also collected from the completed perched zone monitoring wells. Data collected from the three initial perched zone monitoring wells combined with data collected from the eight piezometer were evaluated and used to design the second phase of field investigation activities. This evaluation was presented to EPA in Technical Memorandum (TM) 97-4.

  The second phase of field investigation included the installation of a second monitoring well next to monitoring well MW-3. The second well (MW-3S) was screened from 30 to 40 feet which is the depth interval where the highest concentration of DBCP was detected during Hydropunch sampling in MW-3. The second phase also included the installation of additional perched zone monitoring wells downgradient of MW-3. Borehole MW-4 was drilled approximately 150 feet northeast MW-3. No water was encountered during drilling of MW-4 which indicates that the perched groundwater system does not extend to this location. As such, a monitoring well was not constructed at this location. Two additional monitoring wells (MW-5 and MW-6) were installed within the perched groundwater system. MW-5 and MW-6 were installed

approximately 110 and 235 feet east/southeast of MW-3, respectively. Data from these wells were used to further define the lateral migration of COPCs in the perched groundwater system.

Slug tests were performed in 2-inch diameter monitoring wells MW-1, MW-2, MW-3, MW-3S, MW-5, MW-6 and in 1-inch diameter piezometers P-3, P-4 and P-6. The objectives of the testing program were to derive hydraulic parameters that may be used to both help estimate the lateral and vertical extent of COPC impacts in the groundwater system, and to evaluate and select remedial alternatives, if deemed to be necessary.

- Perched Groundwater Monitoring Well Sampling Program - In addition to the perched groundwater sampling conducted during monitoring well drilling and well installation, a quarterly groundwater sampling program has been established for the six perched groundwater monitoring wells (MW-1, MW-2, MW-3, MW-3S, MW-5 and MW-6).

  The first round of perched groundwater sampling was completed in September, 1997, and included all perched zone monitoring wells except MW-6 which had not yet been drilled. MW-6 was first sampled on October 24, 1997. EPA's oversight consultant, ICF Kaiser, collected a split sample from MW-6 during sampling conducted in November 1997. By the end of July 1998, five complete sample rounds had been completed from the six perched zone monitoring wells. At the request of EPA, existing perched extraction well no. 9 has been added to the perched groundwater monitoring program and was included in sampling conducted since December 1997.

**Basal Aquifer Investigation** - The Work Plan (ICF 1997) and Field Sampling Plan (Golder 1996a) outlined a phased approach for the basal aquifer investigations. The first step of this phased approach was to conduct a series of activities, termed "vertical profiling" to evaluate the vertical distribution of chemicals within the Kunia Well, the possibility of chemical migration through the well's annulus from the perched groundwater aquifer to the basal aquifer, and the suitability of the Kunia Well for use as a monitoring well. In order to meet these aims, the approach presented in the Work Plan included the following items for vertical profiling:

- Point sampling from discrete depths within the Kunia Well water column, to assess the vertical distribution of chemicals within the well and aquifer;
- Temperature/fluid resistivity logging to identify possible preferential flow zones into or out of the well, and natural gamma logging for stratigraphic interpretation; and
- The performance of a video log of the interior of the well to assess the condition of the well casing/screen and to visually check for possible inflow of perched groundwater into the well.

Preliminary results of the vertical profiling activity were originally presented to EPA in TM 97-2. Based in part on these results, which showed that the uppermost sample collected in the well (at the water table surface) exhibited the lowest concentrations of COPCs, it was concluded that the well does not currently serve as a conduit for chemical migration, and the well was deemed suitable for use as a monitoring well and for aquifer testing. As such, it was proposed that a replacement for the Kunia Well not be installed, and the RI proceed with installation of a downgradient basal well and performance of the two-well pumping test. The rationale and justification for the pumping test, as well as the design of the downgradient well were presented in TM 97-3, and were subsequently approved by EPA.

Therefore, following the completion of the vertical profiling, the basal aquifer investigation proceeded with the following field investigative items:

- Drilling and installation of a 993.5-ft deep, 8-inch diameter downgradient Basal Well, located some 156 ft south of the Kunia Well;
- Performance of a two-well pumping test using the Kunia Well as the pumping well, and the new downgradient Basal Well as the observation well, in order to assess site specific hydraulic properties and obtain chemical data; and
- A program of periodic basal well sampling, involving the Kunia Well, new downgradient Basal Well, and selected regional basal aquifer wells. The Kunia Well and the new Basal Well were sampled during Oct-97, Nov-97, Dec-97, Jan-98, May-98 and Jul-98. EPA's oversight consultant, ICF Kaiser, collected split samples from the Kunia Well and the new Basal Well during the sampling conducted in November 1997. HDOH also collected split samples on several occasions. Analytical results of the split sampling were consistent with results of samples collected by Golder. Additional sampling of the Kunia Well was conducted during the pumping test performed in Oct-97 and Nov-97 to investigate potential changes in COPC concentrations during sustained pumping of the well.
- Sampling of regional basal groundwater monitoring wells proposed in the Work Plan including the "Navy Well," the Hawaii Country Club Well, and a well at the Waikakalaua FSA area (well ST12MW05). Groundwater samples were collected from the Navy Well during Oct-97, Jan-98, May-98 and Jul-98. The Hawaii Country Club Well was sampled Nov-97, Feb-98, May-98 and Jul-98. The Waikakalaua FSA well ST12MW05 was sampled in Feb-98. The Waikakalaua FSA well ST12MW05 was determined to be neither up- or down-gradient of the Kunia Village Area and as such provided little or no benefit to the RI program and was therefore not sampled during the subsequent monitoring rounds. Data collected during the RI indicated that sampling from the Honouliuli II series of wells would provide additional water quality data from a portion of the Waianae aquifer that is potentially downgradient of the Kunia Village Area. As such, the Honouliuli II Well #2303-03 was added to the regional basal groundwater sampling program and was sampled in May-98 and Jul-98. The objectives, rationale and justification for the addition of the Honouliuli II well and the

elimination of the Waikakalaua FSA well were presented to EPA in Technical Memorandum 98-2. Verbal approved was received from EPA in May 1998.

Groundwater samples collected from Kunia Village Area basal wells, regional basal wells and perched aquifer monitoring wells were analyzed for the full COPC list of constituents which includes: VOCs via EPA Method 8260, lindane, toxaphene and heptachlor by EPA Method 8080, EDB/DBCP by EPA Method 504.1, TPH-Diesel using EPA Method 8015M, PAHs by EPA Method 8310, bromacil and diuron (Method 632), ametryne (Method 619), and fenamiphos (Method 8141).

**Other Potential Source Areas** - The Other Potential Source Areas were selected by EPA based upon historical activities at the Oahu Plantation and were identified in the RI/FS Work Plan. The primary purpose for evaluation of these sites was to determine whether they pose environmental risks that require further characterization. The following sampling approach was applied in the other potential source areas to satisfy the specific field investigation objectives detailed in the Work Plan.

Perimeter Areas of the Kunia Village Area - The Work Plan identified areas where empty drums appeared to have been stored around the perimeter of the Kunia Village Area. One area is on the west side of the maintenance building; the second area is north of the Former Fumigant Storage Area. The Strataprobe drilling/soil sampling system was used to collect four perimeter area soil samples at a depth of five feet from these areas. The samples were analyzed for volatile organic compounds (VOCs) by EPA Method 8260 and for TPH-diesel using EPA Method 8015 Modified. In addition, one sample was analyzed for the full COPC list of compounds.

Former Fumigant Storage Area Near Field 32 - Between the early 1940's and 1955, a soil fumigant cylinder and drum storage area were operated by DMC in a pineapple field area located near the current pineapple Field 32. The Former Fumigant Storage Area near Field 32 was approximately located based upon preliminary reconnaissance by a former DMC truck driver using maps from a previous 104(e) response. The area encompasses approximately 90 feet by 110 feet. There are no records of soil fumigant spills occurring in this area.

The Work Plan specified the completion of nine soil borings in this area on a triangular grid with approximately 33-foot spacing between holes. Soil samples were collected using the Strataprobe from depths of 0.5, 2, 4, 10, 15, and 25 feet bgs. All samples were analyzed for VOCs by EPA Method 8260 and a subset of approximately 20% were analyzed for the full COPC list.

Empty Fumigant Drum Burial Sites - In the Work Plan five of the 22 identified empty drum burial sites were selected for investigation. The sampling sites were chosen based upon accessibility, geographic distribution, and to sample the potentially worst case scenario in Field 60 where 8 of the 22 sites are located. Judgmental sampling activities were used to sample soils in the most likely areas where chemicals may be detected related to previous site activities. The five sites selected in the Work Plan for investigation include:

- Empty Drum Burial Site behind the Poamoho Crateyard;
- Empty Drum Burial Site in Field F-90A (previously designated as Field 94);
- Empty Drum Burial Site in Field F-60;
- Empty Drum Burial Site in Field F-31 (Field F-31 was substituted for Field F-08 for access reasons after receiving EPA approval); and
- Empty Drum Burial Site in Field F-32.

The sites were approximately located in the field using maps provided by EPA based upon preliminary DMFP reconnaissance. Geophysical equipment was used in order to further delineate the boundaries of the five empty drum burial sites. Three Strataprobe boreholes were drilled at each empty drum burial site in the area identified by the geophysical surveys to have the highest potential to contain buried material. Soil samples collected from three of the five empty drum burial sites were analyzed for VOCs by EPA Method 8260. A subset of 50% of soil samples were also analyzed for lindane, toxaphene, heptachlor (EPA Method 8080), bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141). In addition, 10% of the soil samples were also analyzed for TPH-diesel using EPA Method 8015 Modified.

Physical evidence of locating an empty drum burial site was not obtained at two of the initial sites investigated (Field F-31 and F-32). Therefore, additional geophysical surveys were performed at empty drum burial sites in Field F-60 where 8 of the 22 total buried drum sites are located. The geophysical survey successfully determined the location of two additional empty drum burial sites in Field F-60. Soil sampling and chemical analysis were completed at these two additional sites as described above.

Former Underground Storage Tank (USTs) Sites - Three former underground storage tank (UST) sites were investigated as part of the RI (the Poamoho Crateyard, Maintenance Building Dip Pan, and Field 9 Booster Pump former USTs). UST investigation included collection of soil samples in the areas where USTs had previously been located. The former UST sites had been permanently closed by removal prior to the HDOH requirements for submittal of closure reports implemented in 1987. The RI sampling was designed to supplement previous sampling at the sites and document UST closure.

All soil samples collected at former UST sites were analyzed for TPH-Diesel using EPA Method 8015 Modified. In addition, TPH-Oil was quantitated at the location of the Maintenance Building Dip Pan. TPH-Gas was quantitated at the former UST location in the Poamoho Crateyard. Soil samples with a TPH concentration in excess of 100 mg/kg were also analyzed for BTEX using EPA Method 8020, for PAHs by EPA Method 8310, and cadmium and lead by ICP.

Methyl Bromide Cylinder Burial Site in Field 71 - The Work Plan and FSP describe a buried cylinder containing approximately 43.5 pounds of methyl bromide which was reportedly buried in Field 71. Based on site maps provided by DMC to the EPA, the approximate location of the buried cylinder site was staked by DMFP personnel.

Geophysical survey equipment was used in an attempt to locate the precise location of the buried cylinder.

Although no definitive burial area was located using the geophysical survey, backhoe exploratory pits were excavated in the areas where two minor magnetic anomalies were identified. A third pit was dug in the area staked based upon historical data. The excavated soil and the excavation pits were inspected for any indication of buried debris. A Microtip photo ionization detector was also used to screen the soil for any indication of volatile organic compounds. No indications of the buried methyl bromide cylinder were identified in any of the excavation pits; therefore, no soil samples were collected for chemical analysis.

Current Soil Fumigant Storage Facility - The Current Soil Fumigant Storage Facility, a concrete-lined above ground product storage facility, was visually inspected by EPA and Golder personnel during a site tour on April 29, 1997. In accordance with the Work Plan, no sampling is required at the facility since there is no evidence that a release of hazardous substances has occurred.

Golder personnel further inspected the Current Soil Fumigant Storage Facility on August 22, 1997 and conducted a photographic documentation. The facility contains two 5,000 gallon stainless steel product storage tanks. The tanks currently contain Telone II (which consists of 1,3-dichloropropene). Both tanks are contained in a covered concrete lined containment area and can be visually inspected for cracks, leaks or spills. Dispensing hoses are equipped with vapor return lines. To prevent corrosion, the tanks are equipped with air scrubbers and are inerted with a nitrogen blanket. The tanks are inspected daily by DMFP personnel during routine handling activities. In addition, representatives from Dow Chemical Company perform annual inspections of the Current Soil Fumigant Storage Area. Dow Chemical Company also requires specific safety handling procedures of Telone II which are followed by DMFP personnel.

Excavation Pit Soils Natural Attenuation Area in Field 8 - Soils excavated from the Kunia Village Area during the 1981 and 1983 soil removal actions were spread in a thin layer over an approximate 20 acre pineapple field area in Field 8 which is located approximately 1,700 feet west of the Kunia Village. This was conducted with approval from the State of Hawaii to allow volatilization and natural attenuation to occur. The State's rationale for permitting natural attenuation was that the soil fumigants were still registered for agricultural uses in pineapple fields at that time.

Although the excavation pit soils natural attenuation area in Field 8 was not identified as an Other Potential Source Area in the RI/FS Work Plan, EPA requested that data be collected from this area to determine if COPCs were present in vadose zone soils at concentrations which pose a risk to human health or threat to groundwater. Investigation of this area was performed by collecting soil samples from the approximate depths of 2, 10 and 15 feet in each of nine borehole locations distributed evenly throughout the natural attenuation area. Soil samples were collected using the Strataprobe. All soil samples were analyzed for VOCs by Method 8260. In addition, 20% of all samples were analyzed for lindane, toxaphene and heptachlor (Method 8081), and ten percent were analyzed for TPH-diesel (Method 8015M).

## GEOLOGY AND HYDROGEOLOGY

**Geology.** The Island of Oahu is comprised of the remnants of two late Tertiary shield volcanoes and their associated rift zones. The western part of the island is the eroded Waianae volcano (about 3 million years old), which was the first of the two volcanoes to emerge above sea level; the eastern part of the island consists of the eroded dome of the Koolau volcano (about 2 million years old). The Waianae dome, because of its earlier emergence, was deeply eroded before the Koolau dome reached its maximum height. Piling up of lavas from the Koolau dome occurred on top of the older, eroded slopes of the Waianae dome and eventually produced the broad gently sloping feature in the central area of Oahu called the Schofield plateau.

Geologic materials present in the vicinity of the Kunia Village Area include Waianae basalts to the west, Koolau basalts to the east and, directly underlying the Kunia Village Area, the weathered remnants of basaltic lavas. The surface contact of the Waianae basalts is some 4000 ft to the west of the Kunia Village Area. The dip of the Waianae basalts located to the west of the Kunia Village Area is variable, but is generally about 8° (to the east).

Near surface materials consist primarily of the weathered remnants of the original basaltic surface. In situ decomposition of basaltic bedrock has progressed to depths of approximately 100 to 200 ft bgs. Near surface soils consist of several feet of a deep-red lateritic soil lithosol having a loose, and generally porous structure. Underlying the surface soil is the subsoil, which extends to depths of about 10 to 30 ft. The subsoil is similar to the surface soil in texture and mineralogy but has larger and more distinct structural units. The subsoil grades with depth to saprolite, which is a highly weathered basalt that retains some textural and structural features of the parent rock, such as vesicles, fractures and relict minerals. Saprolite is a clay-rich thoroughly decomposed rock formed by in-situ weathering of the basalt. Beneath the saprolite lies basalt. In places, the basalt immediately beneath the saprolite exhibits some moderate weathering. This zone of weathered basalt is a transitional zone between the highly weathered saprolite and fresh basalt.

As basalt weathers to saprolite, its pore structure is altered and, generally, permeability is decreased as secondary clay minerals fill in pore spaces. In some areas, the permeabilities are low enough to create locally perched water tables within the saprolite zone. The saprolite generally has a thickness of about 50 to 150 ft.

In the vicinity of the Kunia Village Area, this sequence of surface soil, subsoil and saprolite is typical and generally mantles the basalt which is encountered at depths of approximately 150 to 200 ft below ground surface (bgs). Beneath the saprolite lies the moderately weathered basalt and unweathered basalt, which comprises the remainder of the unsaturated zone and basal aquifer.

The saprolites of the Kunia Village Area are believed underlain by basalts of the Koolau volcanic series, given the location of the surface contact of the Waianae some 4000 ft to the west. The contact between the Koolau and Waianae basalts therefore is present at

depth beneath the Kunia Village Area. The depth to the contact between the basalts has not been previously defined for the Kunia Village Area. Based on a projection of the surface contact of the Waianae basalts, however, and assuming a dip of approximately 8° to the east, the contact between the Waianae and Koolau basalts is believed to occur no deeper than about 500 to 600 ft below ground surface. This places the contact between the Koolau and Waianae lavas at an elevation above the water table surface which occurs at about 825 ft below ground surface.

**Hydrogeology.** The most extensive bodies of freshwater on Oahu occur as basal groundwater. Basal groundwater occurs when fresh water percolates into the saturated zone and displaces the underlying sea water. The accumulating fresh water forms a lens-shaped body with a surface that extends above the surface of the salt water due to the contrast in densities between freshwater and sea water. The water table or potentiometric surface of a basal-water body is typically rather flat and is no more than several feet to several tens of feet above sea level. The predominant volume of the freshwater body lies below sea level.

The lavas from the Koolau volcano have the greatest areal extent on Oahu and comprise the largest and most significant basal aquifers. Lavas from the Waianae volcano are also comprise significant aquifers. The permeability of the unweathered rock that makes up the basal aquifers is generally high. The principle flow structures contributing the high permeability are clinker layers associated with a'a, lava tubes in pahoehoe, irregular openings between and within the flows, and contraction joints. Because most of the features which contribute to permeability lie parallel to flow surfaces, the stack of tabular units may be several orders of magnitude less conductive vertically than horizontally. Vesicles which make up a large part of the total volume of the lavas and contribute greatly to the porosity, are seldom interconnected and have little effect on permeability. Connected porosity (through which water may flow) is believed to be generally less than 10%.

The Pearl Harbor Basal Water Body, comprised of lava flows associated with the Koolau and Waianae rift zones, serves as a primary source of potable and irrigation water for Honolulu and the island. Lavas of the Waianae and Koolau volcanoes comprise separate sections, or hydrologic units, of the Pearl Harbor Basal Aquifer, informally termed the Waianae aquifer and Koolau aquifer. The presence of these separate areas has been inferred by observed head drops across the erosional unconformity between the two lavas, and differing water level trend patterns in wells installed in the two lavas. The differences have been attributed to the presence of a partial groundwater barrier along the contact between the Waianae and Koolau lavas. The barrier is comprised of a weathered zone and accumulations of alluvium, separating the lower, older Waianae lavas from the younger Koolau lavas. Head drop across the unconformity is about 2 to 3 feet with heads in the Koolau being higher. Therefore, flow across the contact is always from the Koolau to the Waianae sections. This flow is the major source of recharge to the Waianae aquifer.

The Kunia Village Area is located overtop the Pearl Harbor Basal Water Body near the contact between the Waianae and Koolau aquifer portions of the basal aquifer. The

contact between the Koolau and Waianae basalts is generally mapped as lying along the exposed surface contact of the two units. This contact is approximately 4000 ft west of the Kunia Well site. Since the Waianae basalts dip from 5 to 10 degrees to the east, the effective separation lies further to the east. At a dip of 10 degrees, the sea level contact (approximately the water table surface) is over 1 mile to the east of the surface contact. At a dip of 5 degrees, the sea level contact is even further to the east. This indicates the Kunia Well is constructed in the Waianae aquifer. This conclusion is supported by an analysis of hydraulic gradient data between the Kunia Well/Basal Well and existing monitoring wells known to be completed in the Waianae and Koolau aquifers.

## CONCLUSIONS OF THE REMEDIAL INVESTIGATION

**Conceptual Hydrogeologic Model.** Based on analysis of the geologic and hydrogeologic data collected during this RI, the following conceptual hydrogeologic model has been developed to describe groundwater flow at the Kunia Village Area:

- Surficial soil and saprolite occur to depths of approximately 80 to 100 ft and are underlain by approximately 100 ft of unsaturated, weathered basalt prior to the occurrence of unweathered basalt at 200 ft depth. A near-surface perched aquifer is confined to the saprolite material above the weathered basalt.
- Surface soil and saprolites are of relatively low permeability, with horizontal hydraulic conductivity on the order of 0.01 to 1 ft/day and vertical hydraulic conductivity about one order of magnitude less. Surface water runoff from the Kunia Village Area is concentrated in the pit area due to local topography. Low hydraulic conductivity of the surface soil and saprolites combined with surface water flow patterns creates locally saturated (perched) conditions in the saprolite in the pit vicinity.
- Horizontal flow in the perched aquifer occurs to the north-northeast. The extent of the perched aquifer is limited however to the general area south of the ephemeral gulch. North of the gulch the saprolites are unsaturated. Flow from the perched aquifer is primarily vertically downward due to the higher permeability of the underlying basalt. Evidence of this downward flow is the high downward gradients (on the order of 0.5 to 1) in the saprolite and absence of saturated conditions in the saprolite north of the gulch area. There are no surface seeps of perched aquifer groundwater or points of perched groundwater discharge to surface water (other than overflow from the pit resulting from extremely high precipitation).
- Downward migration occurs from the perched aquifer through the unsaturated basalts to the water table. Immediately beneath the saprolite perched aquifer, approximately 100 ft of weathered basalt is present above fresh basalt. The weathered basalt consists of a transitional zone between the saprolite and unweathered basalt with hydraulic properties intermediate between the two materials. Hydrologic data collected during perched aquifer drilling indicate the weathered basalt zone is unsaturated. Hydraulically, it is therefore an element of the unsaturated basalt sequence which extends from the base of the saprolite to the water table surface.

- At depth beneath the Kunia Village Area, there are indications (from Basal Well drill cuttings, natural gamma logging of the Kunia Well and Kunia Well construction) of a possible perched layer. This zone is interpreted to consist of a weathered zone along the Koolau/Waianae contact. Due to the small inclination of the potential contact, its irregular surface, and the high permeability of the underlying unweathered lava, infiltrating perched water which may collect within this zone will preferentially drain through the unconformity to the Waianae basalts and the Waianae basal aquifer below. Any impacts to basal groundwater are therefore limited to the underlying Waianae aquifer.
- The saturated basalt is highly permeable, with groundwater flow at a gradient of about 1 to 1.5 ft/mile. Hydraulic conductivity is on the order of about 2000 ft/day. Effective porosity of the basalts is about 0.05 to 0.10. The best estimate of average groundwater flow velocity in the saturated basalt is on the order of about 1000 to 1500 ft/year or about 3 to 4 ft/day.
- A variety of hydrogeologic data, consisting of Kunia Village Area stratigraphic information, the projected extension of the Waianae surface exposure, and regional water level data indicate that the basal aquifer beneath the Kunia Village Area occurs within the basalts of the Waianae volcanic series. The direction of groundwater flow in the Waianae aquifer is to the south-southwest.
- Within the basal aquifer, flow across the Koolau/Waianae unconformity is from the Koolau to the Waianae due to higher hydraulic heads in the Koolau. Therefore, the Waianae does not discharge to the Koolau. Since impacts from infiltrating perched groundwater are limited to the Waianae aquifer, all potential downgradient receptors are therefore located within the Waianae aquifer only. Discharge of the Waianae aquifer would be to downgradient wells, springs, and via leakage through the coastal caprock.
- The HCC well is the nearest well potentially downgradient of the Kunia Village Area (approximately 1.5 miles to the south). Hydrogeologic data are not definitive as to which aquifer the well is constructed within. However, the best professional judgement is that the well is completed in the Waianae aquifer. The estimated travel time to the HCC well from the Kunia Village Area is about 5 years or less. Other downgradient wells in the Waianae aquifer include the Honouliuli BWS wells and the US Navy's Barber's Point Shaft. All existing wells to the east of the Honouliuli wells, including the Kunia I/II wells, are constructed in the Koolau aquifer.

**Nature and Extent of Contamination.** The following is a summary of chemical compounds detected above regulatory screening criteria in each of the study areas investigated as part of this Remedial Investigation.

Kunia Village Area Soil Samples - EDB, DBCP and other volatile organic compounds were not detected in Kunia Village Area shallow vadose zone soils. With the exception of one soil sample that contained total petroleum hydrocarbon compounds (TPH) in excess of Hawaii regulatory standards, there were no COPCs detected in shallow vadose zone soil samples above the EPA region IX residential PRGs. DMFP in consultation with

the HDOH excavated the TPH impacted soils, collected confirmatory cleanup samples from the excavation pit, and treated the excavated soils by thermal desorption in compliance with applicable regulations. Soil gas samples collected in the vadose zone did not contain concentrations of volatile organic compounds that would exceed regulatory screening criteria in the ambient air.

Additional Soil Samples in the Former Fumigant Storage Area - Several samples collected from soils at depths of 25 feet and deeper within the Former Fumigant Mixing Area had detected concentrations of EDB, DBCP and DCP. In general, the highest compound concentrations were typically detected at the base of the perched groundwater system. One exception to this is elevated levels of DBCP and DCP detected at depths of 30 to 40 feet in two boreholes located in the northeastern portion of the Former Fumigant Storage Area. Concentrations detected do not indicate presence of dense nonaqueous phase liquid (DNAPL) in these boreholes.

Kunia Village Area Surface Water - Three surface water samples were collected along the flowpath of the ephemeral gulch north of the Former Fumigant Mixing and Storage Areas. EDB and DBCP were detected in one of the samples at concentrations of 170 $\mu$g/L and 0.4 $\mu$g/L, respectively. A grab sample from the excavation pit collected at approximately the same time contained similar concentrations of EDB and DBCP (167 and 0.3 $\mu$g/L, respectively). Water only flows in the gulch during heavy rainfall, and samples were collected during an unusually heavy rainfall event. During the time when the surface water samples were collected (March 1997) water within the excavation pit had risen to a historically high level due to the record rainfall during the winter of 1996-97, and appears to have been flowing into the ephemeral gulch at a point where the surface water sample which exhibited the EDB/DBCP detections was collected. This surface water sample contained similar concentrations of EDB and DBCP as was observed in the excavation pit water sample, and therefore the EDB/DBCP detections are believed to be the result of water from the excavation overflowing into the gulch. The other two samples collected in the ephemeral gulch did not contain detectable levels of EDB and DBCP. Bromacil and lindane were also observed in surface water samples, but at concentrations below MCLs or PRGs. With EPA's approval, DMFP will construct an earthen berm to prevent potential future stormwater runoff from the excavation pit as an interim measure during completion of the RI/FS.

Kunia Village Area Perched Groundwater - Samples collected from portions of the perched groundwater system beneath the Kunia Village Area indicated the presence of ethylene dibromide (EDB), 1,2-dibromo-3-chloropropane (DBCP), 1,2-dichloropropane (DCP), 1,2,3-trichloropropane (TCP), benzene, and lindane in excess of MCLs or PRGs. The concentrations of these compounds are generally lowest in the Kunia Well Spill Area and the Former Fumigant Mixing Area. The highest detected concentrations are generally detected in the Former Fumigant Storage Area in the vicinity of wells MW-3 and MW-3S.

Hydropunch sampling of the perched groundwater system in these three areas indicate that concentrations of these compounds are generally highest at the base of the perched groundwater system. One exception to this is the concentrations of DBCP and DCP

detected in MW-3S which is installed in the upper portions of the perched aquifer in the Former Fumigant Storage Area. The detected concentrations of DBCP and DCP in MW-3S are greater than the levels detected at the base of the perched aquifer in this area as determined by sampling MW-3. Concentrations of DBCP in MW-3S are greater than 1% of the compounds solubility, which is an indication of the presence of DNAPL. Given the fact that indications of DNAPL were not detected elsewhere, this is believed to be a small, isolated occurrence. Cis- and trans- 1,3-dichloropropene were detected in well MW-3S only during the September 1997 sampling. The detected concentrations were in excess of PRGs.

Basal Aquifer Sampling Results - The presence of COPCs in the basal aquifer beneath the Kunia Village Area was investigated through the collection of groundwater samples from the Kunia Well and the new Basal Well (State Well No. 2703-02). Multiple samples have been collected from both wells and tested for the full list of preliminary COPCs assigned in the RI/FS Work Plan (ICF 1997). EDB, DBCP and TCP are the only compounds which have been detected in either well above HDOH drinking water MCLs. The concentrations of EDB and DBCP detected in the Kunia Well ranged from less than the detection limit to 0.22 $\mu$g/L and 0.64 to 1.4 $\mu$g/L, respectively. The concentrations of EDB and DBCP detected in the Basal Well ranged from 0.1 to 0.26 $\mu$g/L and 0.66 to 0.93 $\mu$g/L, respectively. The Hawaii drinking water standard for EDB and DBCP is 0.04 $\mu$g/L. The concentrations of TCP ranged from non-detected to 1.0 $\mu$g/L in the Kunia Well and non-detected to 0.8 $\mu$g/L in the Basal Well. The Hawaii drinking water standard for TCP is 0.8 $\mu$g/L.

Regional basal wells were also included in the groundwater sampling program: the "Navy Well", Hawaii Country Club (HCC) Well, Well ST12MW05 at the Air Force Waikakalaua Fuel Storage Annex (FSA), and Honouliuli Well 2303-03. The Navy Well is an upgradient well located approximately 1 mile north of the Kunia Village Area. The well is completed within a transitional zone between the Schofield High-level Water Body and the Pearl Harbor Basal Aquifer. TCE was detected in the Navy Well at a maximum concentration of 3.0 $\mu$g/L. The HCC well, located approximately 1.5 miles south of the Kunia Village Area, is the nearest potentially downgradient well. While there is some uncertainty as to which aquifer the well is completed in, the best professional judgement is that the well is completed in the Waianae aquifer. However, even if the well is within the same aquifer as the Kunia Well/Basal Well, it may not be located on the downgradient flow path from the Kunia Village Area. DBCP was detected in the HCC well during three sampling rounds at concentrations ranging from 0.038 to 0.071 µg/L. DCP and TCP were detected only during the Jul-98 sampling round below the laboratory's practical quantitation limits at estimated concentrations of 0.14 and 0.22 µg/L, respectively. The drinking water screening levels for DCP and TCP are 5.0 and 0.8 µg/L, respectively. No other compounds were detected in the Hawaii Country Club well. TCE was detected at a concentration of 0.5 µg/L in well ST12MW05. The Air Force well is located approximately 1.5 miles east of the Kunia Village Area and is believed completed within the Koolau portion of the Pearl Harbor aquifer. There were no compounds detected in the Honouliuli Well during the May-98 and July-98 sampling rounds.

Other Potential Source Areas - Other potential source areas identified in the RI/FS Work Plan (ICF 1997), two additional empty drum burial sites, and the natural attenuation area in Field 8 were investigated as part of the site RI. With one exception, no COPCs were identified at any of the other potential source areas above residential PRGs or Hawaii action levels for TPH. The one exception is the presence of TPH diesel compounds detected near a former underground storage tank located at the Field 9 Booster Pump site. Soil samples collected at depths of 16 ft and 25 ft below ground surface had detected TPH concentrations in excess of the State of Hawaii Tier 1 Action Levels. DMFP has developed a Corrective Action Plan for the Field 9 Booster Pump that was implemented in September 1998.

**Fate and Transport.** In support of the Baseline Risk Assessment and Feasibility Study, fate and transport analysis was conducted to estimate exposure point concentrations for the relevant exposure pathways. The primary aims of this analysis were as follows:

- Identification of the relevant contaminant exposure pathways. An exposure pathway describes the processes that link a chemical source to a potential receptor. The significance of pathways identified previously in the Site Conceptual Model Technical Memorandum and Work Plan was re-evaluated in this RI based on the recent data collected during the RI;
- Assessment of the environmental fate of COPCs along these pathways in order to describe the behavior of each COPC in the environmental media in which it is transported; and
- Estimation of the resulting exposure point concentrations of COPCs to potential pathway receptors.

Only one of the preliminary exposure pathways (which also requires fate and transport analysis) included in the SCM TM is believed to be complete based on an evaluation of RI data results. This pathway involves the potential exposure to COPCs via groundwater in the basal aquifer. This is the only pathway which requires a fate and transport evaluation in this RI. Therefore, the focus of the transport analysis was on the basal aquifer, as exposure may occur only via the basal aquifer groundwater. The perched aquifer is not a drinking water source, nor does it have any significant interaction with the surface environment. It is significant only with respect to its potential impacts to the basal aquifer. The primary aim therefore was to estimate the potential receptor point concentrations in the basal aquifer which may occur from the Kunia Village Area basal groundwater impacts.

The general approach was to use the contaminant transport model, BIOSCREEN, to assess the potential downgradient extent of COPC migration from the Kunia Village Area in the Waianae aquifer. Modeling was conducted for the following two sets of analyses:

1. Modeling of the current downgradient impacts due to historical (post-1980) COPC occurrences in basal groundwater; and

2. Modeling of future impacts due to the currently observed Kunia Village Area concentrations.

The primary results and conclusions of the fate and transport analysis can be summarized as follows:

- The only significant source of chemicals to the basal aquifer is area wide infiltration of impacted perched aquifer groundwater in the immediate vicinity of the Kunia Village Area. The Kunia Well, while it may have served as a conduit for COPCs in the past, does not currently represent a significant conduit for vertical migration of chemicals to the basal aquifer and has not since about 1990. Even during the time period when the well may have served as a conduit, pumping of the well was sufficient to contain chemicals which reached the basal aquifer via this mechanism. Therefore, fate and transport modeling needs only to consider the impacts from area wide infiltration and not leakage through the Kunia Well annulus. The areal extent of the perched aquifer source to the basal aquifer can be approximated by the area enclosed within wells MW-1 through MW-6. This is an area roughly 300 ft by 300 ft in size.
- Pumping of the Kunia Well prior to the well's disconnection from the potable water supply in April 1980 is believed sufficient to have contained basal aquifer COPCs and prevented migration away from the Kunia Village Area based on capture zone analysis. Pumping after this time through 1994 may have been sufficient to limit, perhaps significantly so, downgradient migration, however it has been conservatively assumed in this RI that pumping after 1980 was not sufficient for containment. Transport modeling of impacts from historical COPC occurrences is therefore conducted for basal groundwater impacts which occurred after April 1980. A moderate and conservative reduction in the strength of the source after 1980 is included in the transport calculation reflecting continued pumping which occurred at the Kunia Well through 1994.
- The modeling is conducted for EDB and DBCP only for the historical modeling runs, and for EDB, DBCP, TCP and DCP for the predictions of future migration. These four compounds are the only compounds consistently detected in the basal aquifer at the Kunia Village Area. Historical data are not adequate to model prior occurrences of TCP and DCP.
- The thickness of basal groundwater which is impacted by chemicals infiltrating from the perched groundwater is small in relation to the screened interval of the Kunia Well. A conservative estimate suggests it does not exceed a thickness of about 1 to 10 ft near the water table surface directly beneath the perched aquifer source area.
- The Kunia Well is located within the source area of COPCs within the basal aquifer, or is extremely close to it, and capture zone analyses confirm that the well draws water primarily from the source area during sampling events. Chemical data obtained from the well can therefore be used to estimate source area concentrations for subsequent transport modeling. Since the well draws water from the entire 150 ft interval, however, and chemicals are believed restricted to the upper 1 to 10 ft, levels observed in the well during pumping

need to be adjusted (upwards) to reflect the levels considered representative of the surface impacted layer. The results of the vertical profiling are believed more representative of these levels than those measured during pumping. Estimates of EDB and DBCP impacts to the basal groundwater from perched groundwater generally support the view that vertical profiling results are representative of the near water table surface source layer. EDB and DBCP levels measured during vertical profiling were 5 to 10 times and 2 to 3 times levels measured during pumping, respectively.

- Any potential receptors of chemicals migrating away from the Kunia Village Area are associated with the Waianae aquifer only, as groundwater beneath the Kunia Village Area is within the Waianae portion of the Pearl Harbor basal aquifer. Koolau aquifer wells, such as the Kunia I and II wells, are not at risk as they are hydraulically separated from the Waianae aquifer by the higher heads of the Koolau aquifer. The higher head is due to the greater recharge that occurs to the Koolau aquifer and the discontinuity between the two aquifers which acts as a barrier to water movement. Potential downgradient receptor points therefore include the HCC well, Honouliuli I and II wells, and possibly other Waianae aquifer wells further beyond the Honouliuli wells, such as the Barber's Point Shaft. Even though the wells are believed installed in the same aquifer as the Kunia Well/Basal Well, however, there is uncertainty whether these Waianae wells are located along the downgradient flowpath from the Kunia Village Area.
- Although there is limited sampling data from the HCC well prior to 1993, the first observed occurrence of DBCP at the HCC well was in 1993. Estimates of groundwater travel time from the Kunia Village Area to the HCC well (about 5 years or less) indicate that DBCP should have been detected at the well earlier than 1993 if it was indeed derived from the Kunia Village Area. It is therefore possible the observed DBCP impacts are not attributable to the Kunia Village Area. Other sources of DBCP are present in Central Oahu which could account for the observances at the HCC well. There is a possibility however that DBCP at the HCC well is attributable to the Kunia Village Area. For instance, if Kunia Well pumping after 1980 was more effective than assumed at containing DBCP, then the travel time of DBCP to the HCC well could have been delayed, and DBCP occurrences at the well could then be attributable to the Kunia Village Area. However, it is not certain that the HCC well is located on the downgradient flowpath from the Kunia Village Area or is in the same aquifer. Due to these uncertainties, it is not possible to determine whether or not the observed DBCP is associated with the Kunia Village Area. If it is assumed the DBCP occurrences at the HCC well are attributable to the Kunia Village Area, it is unlikely that these levels will increase in the future since sufficient time has passed for the peak concentrations of a potential plume to have reached the well (based on travel time estimates).
- For the Honouliuli II wells, travel time estimates indicate that it is likely chemicals would have already reached the wells, if they were to do so, and yet no chemicals have been observed to date, including sampling conducted as recently as May and July 1998.

- BIOSCREEN modeling was conducted for the following two sets of analyses:

  1. Modeling of the current downgradient impacts (for EDB and DBCP only) due to historical (post-1980) COPC occurrences in basal groundwater; and

  2. Modeling of future impacts (for EDB, DBCP, TCP and DCP) due to the currently observed Kunia Village Area concentrations.

- The results of the first set of analyses (modeling of historical impacts) indicate that the anticipated travel distance to the EDB and DBCP MCLs to date, assuming a "reasonable worst case" scenario, is about 4500 feet from the Kunia Village Area for both compounds. Using more typical values for the various transport input parameters results in "average case" estimated travel distances of about 2500 ft and 2900 ft, respectively. The "reasonable best case" estimated travel distances are about 1800 ft and 2000 ft, respectively.

- Basal aquifer impacts may extend beyond these distances, for instance to the HCC well and possibly to the Honouliuli wells, but not at levels above drinking water standards. The model predicts, using the "reasonable average case" input parameters, current EDB and DBCP levels at the HCC well of approximately 0.01 to 0.02 $\mu$g/L (approximately equivalent to the method detection limits). This assumes the HCC well is located along the downgradient flow path from the Kunia Village Area which is not certain. Recent DBCP analytical results for the HCC well were <0.04 (late 1997) and 0.071 $\mu$g/L (early 1998). If the observed DBCP at the well is associated with the Kunia Village Area, then the model used herein is matching the observed data reasonably well. The model predicts declines in DBCP concentrations in the vicinity of the HCC well in the future if the source area declines continue. EDB was not detected at the well during RI sampling activities.

- It is also possible that impacts above the detection limit, but below the MCL, may extend to the Honouliuli wells. Under the reasonable worst case scenario, EDB and DBCP levels are in the range of about .01 to .02 $\mu$g/L. Under the average case scenario, however, the estimated levels for both compounds are less than 0.01 $\mu$g/L. As with the HCC well, it is not certain if these wells are located on the downgradient flow path from the Kunia Village Area. No COPCs have ever been detected at these wells, including sampling conducted as recently as July 1998.

- Modeling of the future impacts from present-day concentrations (which conservatively assumed constant source area concentrations into the future) indicates that the maximum future estimated travel distance from the Kunia Village Area to an MCL concentration is about 3000 ft. for DBCP. The MCL for EDB is estimated to occur at a maximum distance of approximately 2000 ft. The "average estimate" distances, are about 1300 and 2000 feet, respectively, for EDB and DBCP. Estimated travel distances to the DCP and TCP MCLs are much shorter than for EDB and DBCP (less than about 100 ft). These estimated travel distances are much smaller than the EDB and DBCP travel distances due to the fact that the Kunia Village Area DCP/TCP groundwater concentrations are only

very marginally in excess of the MCLs for these two compounds. These modeling results indicate therefore that there is little likelihood of future impacts to any existing downgradient wells at levels above MCLs even if current concentrations remain constant in the Kunia Village Area.

- The estimates of travel distances are based upon conservative assumptions and calculations which included reasonable worst case scenarios and, therefore, likely overestimate actual conditions. For instance, the modeling is based on a water table surface concentration, which ignores typical well construction practices on Oahu where wells are screened over large intervals. Also, no downward gradients or dilution due to infiltrating rain water were assumed. In addition, only a relatively small amount of containment (25%) was assumed from pumping during the period 1980 to 1994, based on the minimum pumping rate over the period. During the early 1980s, when levels of COPCs were highest in the Kunia Well, pumping was considerably greater than the minimum. If a greater amount of containment was occurring than was assumed, then the travel distances and downgradient concentrations (historically observed impacts) would be lower than those estimated herein.

## RECOMMENDATIONS FOR FURTHER WORK

The overall goal of the RI investigations and data evaluation/analysis activities was to define the nature and extent of contamination in soils and groundwater at the known and suspected source areas to support an assessment of potential risks to human health and the environment (to be conducted in the BRA), and to evaluate and select remedial options, if needed, for mitigating any unacceptable risks (to be conducted in the FS).

The nature and extent of contamination has been adequately defined to meet these goals, as discussed below:

- Soil COPC occurrences were found to be very limited in shallow soils, and consisted only of TPH impacts observed in two samples. The detected impacted soil at one of these locations has been removed already, and the other location will be addressed in the context of a separate regulatory program (Hawaii DOH UST regulations). Deeper soils (i.e., deeper than 25 feet), which are periodically saturated in the Former Fumigant Storage Area were found to contain elevated levels of COPCs.
- Surface water impacts were found to be limited as well. No interaction between perched groundwater and surface water is believed to occur. Impacts to surface water are limited to pit water in the Kunia Village Area. Only during extreme rainfall events, when the pit overflowed to surface water in the ephemeral gulch, was there a possible release of COPCs to a surface water course. Additional sampling will be conducted in the ephemeral gulch to confirm that the prior COPC release was due to pit overflow.
- No soil gas samples contained COPCs at levels which would result in the exceedance of ambient air screening values.

- Perched groundwater and basal groundwater do contain COPCs at levels above regulatory screening criteria, which will require assessment in the BRA and FS. The extent of these impacts has been adequately defined however. Perched groundwater impacts are limited to the vicinity of wells MW-1 through MW-6. The impacts of the perched groundwater COPCs to the basal aquifer have been estimated and found to be similar to measured values (vertical profiling results) believed representative of the impacted basal groundwater. The nature and extent of basal aquifer impacts has been determined through groundwater modeling analysis. The results of this modeling are sufficient to determine location specific exposure concentrations in the BRA.

The nature and extent of contamination has been adequately defined to support the completion of the BRA and FS, and therefore, no new major data collection activities are believed necessary.

## RECOMMENDED REMEDIAL ACTION OBJECTIVES (RAOs)

The Remedial Action Objectives (RAOs) for this project were originally defined in the Work Plan (ICF 1997) and included specific goals regarding prevention of exposure and acceptable carcinogenic and non-carcinogenic risks. RAOs were defined for the following environmental media:

- Groundwater (Perched and Basal);
- Soil (Shallow - less than 5 ft bgs);
- Soils (Deep - greater than 5 ft bgs); and
- Surface Water.

Exposure to COPCs via ingestion, inhalation and dermal contact were the relevant exposure mechanisms for groundwater, surface water and shallow soils. For deep soils, the exposure pathway was defined to include leaching of chemicals to perched and basal groundwater.

Based on the RI data collected to date, it is appropriate to re-evaluate these RAOs to determine if they are adequate to address potential risks posed:

- Due to the lack of shallow soil or soil gas COPCs in excess of regulatory screening criteria anywhere on the Oahu Plantation, the shallow soils pathway (involving ingestion, inhalation and leaching) does not include complete exposure pathways. It is therefore appropriate to eliminate RAOs which address shallow soils.
- Groundwater (perched aquifer and basal aquifer) and deep soil media do represent potentially complete exposure pathways. However, in the Work Plan (ICF 1997), no differentiation is made between perched groundwater and basal groundwater with respect to RAOs. Perched groundwater is not used as a drinking water source, although it does discharge to the basal groundwater which is used for drinking water purposes. Nor does perched groundwater,

apart from the excavation pit, have any interaction with surface water. Therefore, it is not appropriate for the RAOs for perched and basal groundwater to be the same. Perched groundwater and deep soils are significant only in their potential for impacting basal groundwater.

- In the Work Plan (ICF 1997), RAOs for surface water address the ingestion pathway and refer to surface water quality standards (Clean Water Act criteria). However, the RI has demonstrated that the only impacted surface water is represented by the water found in the excavation pit. This water is not used as a drinking water source and ingestion is therefore not a reasonable exposure pathway to be assumed. Nor are surface water criteria applicable to this water since the ephemeral pit does not support aquatic life. The relevant exposure pathway for pit water is inhalation and not ingestion.
- RAOs presented in the Work Plan do not address potential ecological receptors. However, the RI results have indicated that shallow soils, and surface water in the ephemeral gulch are not impacted by COPCs. In addition, the ephemeral pit does not support aquatic life. Chemical impacts associated with the Kunia Village Area are not accessible to potential ecological receptors. It is therefore not necessary to designate RAOs related to ecological exposures.

Therefore, based on the above and the preliminary RAOs outlined in the Work Plan, recommended RAOs include the following:

Basal Groundwater

- Prevent ingestion (or inhalation) of water having contaminants over their respective MCLs, or a contaminant specific excess carcinogenic risk greater than one in a million, or a non-carcinogenic hazard index greater than one.
- Prevent ingestion (or inhalation) of water having contaminants with an excess carcinogenic risk for all contaminants greater than one in ten thousand, or a total non-carcinogenic hazard index greater than one.

Perched Groundwater (including Deep Soils)

- Limit discharge of perched groundwater to basal groundwater such that the basal groundwater RAOs are achieved.

Surface Water (excavation pit area only)

- Prevent inhalation of contaminants in water with chemical concentrations in excess of a contaminant specific excess carcinogenic risk greater than one in a million, or a non-carcinogenic hazard index greater than one.
- Prevent inhalation of contaminants in water with chemical concentrations in excess of a carcinogenic risk for all contaminants greater than one in ten thousand, or a total non-carcinogenic hazard index greater than one.

## RECOMMENDATIONS FOR THE FEASIBILITY STUDY

The initial steps of the FS were conducted in the Work Plan (ICF 1997). These included the following:

- Establishment of RAOs for chemicals and media of interest; and
- Identification of the applicable general response actions (e.g., containment, removal, and treatment).

From the applicable response actions, potentially applicable remediation technologies were identified and screened to obtain a set of feasible technologies for use in achieving the RAOs. Alternatives screening in the Work Plan resulted in the determination of a set of preliminary remediation alternatives for soil, and for groundwater, which were retained for further evaluation in the FS. For soils, retained alternatives included:

- No Action;
- Access Restrictions (Institutional controls);
- Containment (e.g., capping - either horizontal, vertical, or both);
- In-situ soil vapor extraction (with or without containment); and
- Ex-situ thermal desorption (presumes excavation).

For groundwater, retained alternatives included:

- No Action;
- Access Restrictions (Institutional Controls);
- Natural Attenuation (with monitoring);
- Hydraulic containment;
- In-situ biological (oxygen enhancement with either peroxide or air sparging);
- In-situ physical/chemical (air sparging); and
- Extraction with ex-situ physical/chemical treatment (air stripping, carbon adsorption, and UV oxidation).

It is appropriate to review the results of the alternative screening conducted in the Work Plan to determine whether it is appropriate at this time to add or remove some alternatives on the basis of RI results and any changes made above to RAOs.

For groundwater, the Work Plan eliminated ex-situ biological treatment as a potential technology for the treatment of extracted groundwater. However, Mink and Yuen, Inc. and DMFP have been pursuing the performance of a treatability investigation to assess the feasibility of using phytoremediation as a means of treating impacted perched groundwater which could be generated via groundwater extraction. The technology involves the application of chemical-containing water to phytoremediation crops in self-contained lined treatment systems.

In addition, it is believed appropriate to include containment (via capping or regrading) as an alternative for perched groundwater. Surface water infiltration through the perched aquifer is the primary source of chemicals to the basal aquifer. In addition, runoff currently collects in the pit area and results in the creation of ponded water during heavy rainfall, which may result in surface water exposures. Pit water can overflow into the ephemeral gulch during extreme rainfall events. Given these factors, it is believed appropriate to include capping/regrading as a means of controlling exposure to surface water contained in the excavation pit and limiting infiltration through the perched aquifer to the basal water table.

Therefore, proposed changes to the alternatives screening conducted in the FS include the addition of two new alternatives for groundwater: ex-situ biological treatment via phytoremediation to be used in conjunction with groundwater extraction, and capping/regrading to limit infiltration and control potential surface water exposures.

## NPL SITE BOUNDARIES

The National Priorities List (NPL) of CERCLA does not describe releases in precise geographical terms. The Del Monte Corporation (Oahu Plantation) Superfund Site is typical of many large facilities where large tracts of land have been included by association with the NPL Site Name as part of the Site although they pose no significant threat to human health or the environment. EPA regulations provide that the nature and extent of the threat presented by a release will be determined by the Remedial Investigation/Feasibility Study as more information is developed on Site contamination.

Based on the results of this RI, the site boundaries of the DMC NPL Site can be described in general geographical terms as the known source areas at the Kunia Village Area and the potential downgradient (or south-southwest) travel distances at or above Maximum Contaminant Levels of Chemicals of Potential Concern in the Waianae portion of the Pearl Harbor Aquifer within the existing property boundaries of the Kunia section of the Oahu Plantation.

DMFP has requested that EPA more accurately define the NPL Site boundaries as described above. This request is currently under consideration by EPA.

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ACRONYM LIST

| | |
|---|---|
| AOC | Administrative Order of Consent |
| ASTM | American Society for Testing Materials |
| ASTDR | Agency for Toxic Substances and Disease Registry |
| BTEX | Benzene, Toluene, Ethylbenzene, and Xylene |
| BWS | Honolulu Board of Water Supply |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| COC | Chain of Custody |
| COPC | Chemical of Potential Concern |
| DBCP | 1,2-dibromo-3-chloropropane |
| DCE | dichloroethene |
| DCP | 1,2-dichloropropane |
| DMC | Del Monte Corporation |
| DMFP | Del Monte Fresh Produce |
| DOH | State of Hawaii – Department of Health |
| DOT | U.S. Department of Transportation |
| DQO | Data Quality Objective |
| EE/CA | Engineering Evaluation/Cost Analysis |
| EDB | Ethylene Dibromide |
| EPA | United States Environmental Protection Agency |
| FID | Flame Ionization Detector |
| FS | Feasibility Study |
| FSP | Field Sampling Plan |
| GAI | Golder Associates Inc. |
| HCC | Hawaii Country Club |
| HDOH | Hawaii Department of Health |
| HSP | Health and Safety Plan |
| ICF | ICF Technology, Inc. |
| MCL | Maximum Contaminant Level |
| MS | Matrix Spike |
| MSD | Matrix Spike Duplicate |
| NPL | National Priorities List |
| PAH | Polynuclear Aromatic Hydrocarbons |
| PID | Photoionization Detector |
| PRGs | EPA Region IX Preliminary Remedial Goals |
| QA | Quality Assurance |
| QAPP | Quality Assurance Project Plan |
| QC | Quality Control |
| RAO | Remedial Action Objectives |
| RCRA | Resource Conservation and Recovery Act |
| RI | Remedial Investigation |
| RI/FS | Remedial Investigation/Feasibility Study |
| RM | Roscoe Moss Hawaii |
| SAP | Sampling and Analysis Plan |
| SCM | Site Conceptual Model |

| | |
|---|---|
| TCE | Trichloroethene |
| TCP | 1,2,3-trichloropropane |
| TPH | Total Petroleum Hydrocarbon |
| TM | Technical Memorandum |
| USCS | Unites Soil Classification System |
| USGS | United States Geological Survey |
| VOC | Volatile Organic Compounds |

Chapter 1

# 1. INTRODUCTION

This report, prepared by Golder Associates Inc. (Golder) for Del Monte Fresh Produce (Hawaii), Inc. (DMFP), presents the results of the Del Monte Corporation (Oahu Plantation) Superfund Site Remedial Investigation. In December 1994, the U. S. Environmental Protection Agency (EPA) placed the Del Monte Corporation (Oahu Plantation) site (the "Site") on the National Priorities List (NPL) pursuant to the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). In September 1995, DMFP on behalf of the Del Monte Corporation (DMC) and RJR Nabisco Holdings Company, signed an Administrative Order of Consent (AOC) with EPA and the State of Hawaii to conduct a Remedial Investigation and Feasibility Study (RI/FS) for the site. This RI report has been prepared in accordance with the AOC, the statutory requirements of CERCLA, and the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988).

The remainder of this chapter will provide the purpose and rationale of the Remedial Investigation including EPA's Site Assessment process used to develop the scope of work for the site. Background information on the Oahu Plantation and an overview of the Superfund RI/FS process is also provided. The last section of this Chapter will provide an outline of the entire RI report.

## 1.1 Purpose and Rationale

The objective of the Del Monte Corporation (Oahu Plantation) Superfund Site RI is to gather and develop the necessary information to assess the nature and extent of chemicals of potential concern (COPCs) in soils and/or groundwater at the known and suspected source areas that have been identified in association with the site. COPCs were determined by EPA and the Hawaii Department of Health based on information regarding historical and current fumigant uses and practices and other practices at the site. COPCs were originally identified in the Site Conceptual Model Technical Memorandum (ICF 1995b), and were subsequently revised and finalized in the RI Work Plan (ICF 1997). The data will be collected to support: 1) an assessment of potential risks to human health and the environment posed by the presence of site COPCs, 2) a determination of the need for further remediation at the site to address any unacceptable risks, and 3) identification, evaluation and selection of remedial alternatives required to meet the site-specific Remedial Action Objectives (RAOs). The RAOs developed by EPA as part of the Work Plan (ICF 1997) and are summarized in Table 1-1. The key concept in the RI/FS process is to gather sufficient information to meet the data needs while recognizing that removing all uncertainty is not necessary or achievable. An additional objective of the RI/FS process is to re-evaluate the completeness and significance of the potential exposure pathways identified during EPA's initial site assessment process.

In order to develop a scope of work, adequate to meet the objectives of the remedial investigation, a thorough research of historical data was conducted by ICF Technology (ICF) under contract to the EPA. Historical data was provided by EPA, the Hawaii

Department of Health, and DMFP. Additional information was obtained through EPA's site assessment process which included the Special Notice Letter 104(e) request and Preliminary Site Assessment. Data on the current site conditions was collected during site visits by EPA and ICF. Site information was compiled and presented in the Data Summary and Evaluation Report (ICF 1995a). Based upon the information presented in the Data Summary Report, the *Site Conceptual Model Technical Memorandum* (SCM TM) (ICF 1995a) was prepared by ICF for the EPA (ICF 1995b). Potential exposure pathways were presented in the SCM TM. Based upon this information, EPA developed a Statement of Work (SOW) to direct the development of a work plan and complete the Site RI/FS.

The scope of work for the RI was first outlined in the Work Plan (ICF 1997). The Work Plan provides the rationale and description of the proposed investigations and data evaluation/analysis activities necessary to determine the nature and extent of COPCs in soils and groundwater at the site and the need for any remedial activities to mitigate unacceptable risks, if any. Details of the field investigation procedures necessary to implement the Work Plan were subsequently presented in the DMC (Oahu Plantation) Superfund Site Field Sampling Plan (FSP) (Golder 1996a). The support project plans include: Health and Safety Plan (HSP), and Quality Assurance Project Plan (QAPP) (Golder 1996b,c).

## 1.2 Background

The Oahu Plantation is a 6,000 acre pineapple plantation currently owned and operated by Del Monte Fresh Produce (Hawaii), Incorporated (DMFP). Corporate ownership and other potentially responsible parties were identified in documents previously provided to EPA. The plantation is located on the western side of the Oahu central plain which stretches between the Waianae and Koolau Mountain ranges (Figures 1-1, 1-2, and 1-3). The plantation has been used for cultivation of pineapple since the early 1940s. The DMFP facility is comprised primarily of agricultural areas but also contains two company operated housing complexes (Kunia Village and Poamoho Village), as well as equipment maintenance areas, pesticide storage facilities, warehouses, and administrative buildings.

From 1946 through April 25, 1980, domestic and agricultural water was supplied to the approximately 700 residents of Kunia Village by the Kunia Well (USGS 2703-01) (Figures 1-3 and 1-4). In April 1977, an accidental spill involving about 495 gallons of the soil fumigant ethylene dibromide (EDB) possibly containing 0.25 percent 1,2-dibromo-3-chloropropane (DBCP) occurred on bare ground within approximately 60 ft of the Kunia Well. The spill resulted from the failure of a defective hose on a bulk transport container owned by Dow Chemical Company (DOW) during transfer operations to an above ground storage tank. EDB contamination was not detected above a detection limit of 0.5 $\mu$g/L in the Kunia Well in testing conducted immediately after the spill.

In 1979, in response to the detection of DBCP in groundwater in California near fumigated farmland, a joint groundwater sampling program was initiated by the

Pineapple Growers Association of Hawaii and the State of Hawaii Departments of Agriculture and Health, to assess the regional presence of DBCP in Hawaiian groundwater. During the course of the program, groundwater samples collected from the Kunia Well on April 14, 1980 indicated the presence of EDB and DBCP at levels of 92 and 11 $\mu$g/L, respectively. The Kunia Well was resampled on April 24, 1980, and EDB and DBCP were detected at 300 and 0.5 $\mu$g/L, respectively.

Based on these results, the well was disconnected from the potable water system in April 1980. Potable water is presently supplied primarily by the "Navy Well" (State Well No. 2803-05), and occasionally since 1991, by Del Monte Well No. 4 (State Well No. 2803-07) located approximately 1.5 miles north of Kunia Village. The supply wells have been approved by HDOH. A packed tower aeration facility was installed in 1989 to remove volatile organic compounds (trichloroethylene) (TCE) possibly migrating in the high level aquifer groundwater from Schofield Army Barracks. The drinking water supply for the Kunia Village has been treated using the packed tower aeration facility since 1991. In September 1997, DMFP entered into a contract with Schofield Barracks to remove TCE from Kunia Village's drinking water supply. Potable water for company housing at Poamoho Village is provided by a municipal water supply.

An epidemiology study conducted by the University of Hawaii and funded by DMC was conducted in 1981 to assess the potential effects of groundwater contamination on the residents of Kunia Village. The results of these studies indicated that there were no acute effects in the exposed population due to the short-term exposures from the Kunia Well.

In response to the detection of the compounds in the Kunia Well, the owner/operator of the plantation at the time, Del Monte Corporation (DMC), initiated soils and groundwater investigation, and remedial cleanup efforts in the vicinity of the Kunia Well. In addition to the Kunia Well spill area, other areas impacted with fumigants near the well were identified, including the Former Fumigant Mixing Area and Former Fumigant Storage Area (Figure 1-4). These areas are located within about 50 to 150 ft northwest of the Kunia Well. The nature of accidental spillage near the former mixing and storage areas may have been intermittent over a span of years, and the quantity of accidental spillage in these areas in unknown.

Remedial efforts associated with these three areas involved removal of about 18,000 tons of soil in 1981 and 1983 (Figure 1-4), and periodic extraction of impacted groundwater from a shallow, perched aquifer beneath the site from 1980 to 1994. The Kunia Well was also pumped about twice a week for 4 to 8 hours between 1980 to 1994 to remove impacted groundwater and limit the potential downgradient migration of chemicals in groundwater. The water from the Kunia Well was used for irrigation of a non-crop grassy area north of the well site. The perched groundwater was used for dust control on in-field pineapple roads away from residential populations.

A Preliminary Assessment/Site Investigation (PA/SI) was conducted at the site in 1990 by EPA. EPA subsequently completed a Hazard Ranking Scoring (HRS) process for the site in 1992 which led to a proposed listing on the NPL.

During 1994, a public health assessment was conducted by the Agency for Toxic Substances and Disease Registry (ATSDR) pursuant to requirements mandated by the proposed listing on the NPL. The ATSDR studied the historical data for the site, including the pre-1980 use of the Kunia Well as the drinking water source. The ATSDR's study also included the previous response activities conducted at the site (i.e., use of water from the Kunia Well for irrigation of non-crop areas and use of water from perched wells for dust control on in-field pineapple roads). In a report dated February 7, 1995, ATSDR concluded that residents of Kunia Village had not been exposed to significant levels of EDB and DBCP in their drinking water, and the Oahu Plantation was classified as a "No Apparent Public Health Hazard" for past and current conditions (ATSDR 1995). It is not anticipated, according to ATSDR, that Kunia Village residents who utilized the Kunia Well as their drinking water source will have any adverse health effects. ATSDR also concluded that the site may pose an "Indeterminate Health Risk," however, for future exposures due to the need to characterize potential impacts on downgradient wells.

The site was added to the NPL on December 16, 1994, and an AOC for an RI/FS and Engineering Evaluation and Cost Analysis (EE/CA) was signed by DMFP and EPA on September 28, 1995. EPA and DMFP agreed on January 23, 1997 to include the soils operable unit in the FS rather than in a separate EE/CA to more effectively complete the remedial evaluation process by considering interactions of soils and groundwater. The AOC Statement of Work (SOW) developed by EPA and the State describes the investigative work at the Kunia Village Area and Other Potential Source Areas required to meet the RI/FS objectives.

Previous remedial activities focused on the spill area adjacent to the Kunia Well and the nearby Former Fumigant Storage Area and Former Fumigant Mixing Area located just to the north of the Kunia Well. A Site Conceptual Model (SCM) Technical Memorandum (TM) and a Data Summary and Evaluation Report (DSER) were prepared for the site by ICF Technology, Inc. (ICF 1995a,b). Based upon an extensive review of historical data the SCM identified the types of contamination potentially present in the soil, perched groundwater, and basal groundwater, and assessed the potential exposure pathways and migration routes associated with each media. The RI process was designed based upon information provided in the SCM and DSER to provide sufficient data to complete the FS and baseline risk assessment.

## 1.3 Overview of the RI/FS Process

In accordance with EPA guidance (EPA 1988), an RI/FS is generally conducted in the following steps:

RI Process

1. Develop and implement an RI program, in accordance with EPA guidance on Data Quality Objectives (DQO) process (EPA 1993).
2. Present and evaluate the RI data.

3. Evaluate the environmental setting of the site. This evaluation uses data obtained during the RI as well as other available information.
4. Estimate the nature and extent of COPCs in environmental media.
5. Estimate the future fate and transport of COPCs in the environment.
6. Evaluate risks for human health and ecological exposure to contamination through the performance of a baseline risk assessment.

FS Process

7. Establish remedial action objectives (RAOs) (cleanup goals) for COPCs and media of interest.
8. Identify the applicable general response actions (e.g., containment, removal, and treatment). From the applicable response actions, identify and screen potentially applicable remediation technologies for each affected media to obtain a set of feasible technologies for use in achieving RAOs.
9. Estimate the areas and volumes of affected media that exceed the remedial action objectives based on information developed in the RI.
10. Assemble the retained technologies into remediation alternatives that cover the full range of possible response actions. The alternatives are then screened based on effectiveness, implementability, and cost to eliminate alternatives that are impractical, infeasible or too costly relative to the other alternatives.
11. Develop and evaluate the retained alternatives in sufficient detail to support selection of a site remedy, which is eventually documented in a Record of Decision (ROD) prepared by EPA.

This RI report, together with the Work Plan (ICF 1997), contain steps 1 through 5. As documented in EPA's letter dated October 8, 1997, EPA approved that Golder Associates on behalf of DMFP conduct a risk assessment. Pursuant to this approval, Golder Associates will take the lead role in consultation with EPA in the performance of the baseline risk assessment. The risk assessment document will be completed as a separate stand-alone report from the RI.

In accordance with the AOC SOW, the RI/FS Work Plan, and other EPA requirements, the FS will consist of a single focused FS for the groundwater and soils operable unit. The soils operable unit will be included in the FS and an EE/CA will not be conducted. This focused approach is intended to expedite the overall process of remedy evaluation and selection. As part of this approach, steps 7 and 8 have already been conducted. RAOs were established by EPA and were presented in the Work Plan (ICF 1997). General response actions and technology screening was conducted in Section 3 of the Work Plan. The FS report will therefore consist of steps 9, 10 and 11 which includes all the remaining steps necessary in a final FS to support selection of a site remedy.

The final RI/FS, and the Baseline Risk Assessment, along with the administrative record, will form the basis for the selection of the site remedy by EPA and the State which will be formerly documented in the Record of Decision (ROD) for the Site.

## 1.4 Report Organization

Consistent with the outline provided in the Work Plan (ICF 1997), this RI report is organized into the following sections:

- Chapter 1, Introduction - This section.
- Chapter 2, Data Collection Activities - This section presents the RI data collection activities by the tasks presented in the Work Plan (ICF 1997).
- Chapter 3, Environmental Setting - This section describes the physical characteristics of the site on the basis of previous studies, referenced information, and the data collected as part of the RI. Physical characteristics discussed include the site location and topography, regional and site geology, hydrogeology, hydrology and meteorology.
- Chapter 4, Nature and Extent of Contamination - This section presents the results of the sampling and chemical analysis conducted for the RI and compares the data to EPA Preliminary Remediation Goals (PRGs), federal drinking water Maximum Contaminant Levels (MCLs), and Lifetime Health Advisory Levels (LHALs) to determine the extent of contamination in site environmental media.
- Chapter 5, Contaminant Fate and Transport - An evaluation of the environmental fate for site COPCs and an analysis of the transport of these chemicals through the relevant environmental media and pathways.
- Chapter 6, Summary and Conclusions - An overall summary of the RI are provided in this section, as well as recommendations for further work, if any is considered necessary.
- Chapter 7, References - This section cites the documentation referenced in the body of this report.
- Appendices - Supporting RI data are included in Appendices A through I.

Chapters 1 through 7 of the report, along with tables and figures, are included as Volume I. Volumes II and III consist of the appendices.

Chapter 2

Chapter 2

# 2. DATA COLLECTION ACTIVITIES

This chapter describes data collection activities completed during the Remedial Investigation. All investigation activities were conducted in substantive accordance with procedures detailed in the *Work Plan for Remedial Investigation and Feasibility Study at the Del Monte Corporation (Oahu Plantation) Superfund Site* (ICF 1997), the *Field Sampling Plan for Remedial Investigation and Feasibility Study at the Del Monte Corporation (Oahu Plantation) Superfund Site* (Golder 1996a) and the *Quality Assurance Project Plan* (Golder 1996c). Deviations from activities identified in the Work Plan and Field Sampling Plan are also presented. Interpretation of the data collected as part of the Remedial Investigation are provided in subsequent chapters of this report.

## 2.1 Introduction

### 2.1.1 General

Based on the results of past field investigations and on the history of site activities, source areas were identified in the RI/FS Work Plan (ICF 1997) where potential hazardous chemicals have been released into the environment. These include the following "known" sources (where chemicals have been observed) which are collectively referred to as the Kunia Village Area:

- Kunia Well Spill Area;
- Former Fumigant Storage Area; and
- Former Fumigant Mixing Area.

Historical data, including the results of past field investigations and site historical information, were reviewed by EPA to identify areas where hazardous materials were used. These areas were presented in the RI/FS Work Plan (ICF 1997) as suspected sources of potentially hazardous chemicals. Releases of potential hazardous chemicals were not known to have had occurred at these areas. The other potential source areas investigated during the RI include:

- Perimeter Areas of the Former Fumigant Storage and Mixing;
- Former Fumigant Storage Area near Field 32;
- Empty Former Fumigant Drum Burial sites;
- Former Underground Storage Tank (USTs) sites;
- Methyl Bromide Cylinder Burial Site in Field 71; and
- Current Soil Fumigant Storage Facility.

Although not identified as an Other Potential Source Area in the RI/FS Work Plan, the Excavation Pit Soils Natural Attenuation Area in Field 8 was also investigated during the RI at the request of EPA. These known and suspected source areas were investigated under the following media-specific groupings:

- **Soils Operable Unit.** The soils operable unit includes surface and vadose zone soils in the Kunia Village Area, as well as soils associated with the Other Potential Source Areas at the site;
- **Surface Water and Sediment.** Surface water and sediments are associated with the ephemeral stream gulch east of the Kunia Village Area, the smaller ravine southeast of the Kunia Village Area, and the associated run-off pathways; and
- **Groundwater Operable Unit.** The groundwater operable unit consists of the perched groundwater zone and basal aquifer in the Kunia Village Area.

The overall goal of the field sampling activities was to estimate the nature and extent of impacts from chemicals of potential concern (COPC) at these known and suspected source areas, and to characterize the chemicals present in sufficient detail to prepare a Baseline Risk Assessment and a Feasibility Study. Data required to support these goals include information on geology, hydrogeology, soils, surface water and sediments, and the nature and extent of chemicals throughout pertinent environmental media at the site. The rationale and approach for site field investigations were evaluated in the RI/FS Work Plan (ICF 1997), using the Data Quality Objective (DQO) process.

The DQO process is detailed in EPA guidance document (EPA, 1993). DQOs are used to develop a scientific and resource-effective sampling design, and are established through a process that is designed to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended application. The DQO process was applied to provide the rationale for sampling to support the objectives of the remedial investigation (i.e., to delineate the nature and extent of contamination at the site and to characterize the chemicals present in sufficient detail to prepare a baseline risk assessment and remedial alternative analysis).

Data collection activities were performed during two primary phases. The first phase of work was conducted during the period of March 3, 1997 to June 5, 1997. The second phase was conducted during August 18, 1997 to October 24, 1997. Phasing the work in this manner was due to: access restrictions to some portions of the Kunia Village Area resulting from unusually heavy rainfall beginning in the fall of 1996 (the Kunia site received over 50 inches of rainfall from November 1996 through March 1997 compared to normal average rainfall during these five months of 22 inches); the need to review field data prior to installation of additional perched zone monitoring wells; the need to complete "step-out" sampling in some areas of the site to define the extent of COPCs; and the requirement to receive EPA approval prior to conducting the two-well basal aquifer test. One benefit of phasing the work is that it provided an opportunity to evaluate the data collected during the first phase to optimize the second phase of investigation to meet the project objectives.

Additional RI data were collected during the quarterly groundwater sampling rounds. Additional soil sampling was conducted during May 1998 and late July to early August 1998.

Physical and chemical data collected in the RI are presented in the following Appendices:

- Appendix A – Analytical Data Summary,
- Appendix B – Borehole and Perched Well Construction Logs,
- Appendix C – Results of Laboratory Physical Testing,
- Appendix D – Geophysical Surveys at Empty Drum Burial Sites,
- Appendix E – Piezometer and Perched Monitoring Well Testing Data and Analysis, and
- Appendix F – Basal Groundwater Supply and Monitoring Well Geophysical Testing and Deviation Surveys.

The following subsections briefly describe the procedures used during site field investigations, as well as the locations and frequency of sampling, and chemical and physical analyses performed.

### 2.1.2 Work Plan Modifications

Some activities outlined in the Work Plan (ICF 1997) were modified and some tasks eliminated due to higher than anticipated groundwater levels and other conditions encountered in the Kunia Village Area, and some new tasks were added. Tasks modifications included:

- The performance of a soil gas extraction test was eliminated due to the absence of detected chemicals in the vadose zone soils above EPA required screening levels;
- Vadose zone soil sampling in the Former Fumigant Mixing Area was conducted using hand driven sampling methods to a depth of four feet (vehicle access into the Former Fumigant Mixing Area was not possible due to the steep sidewalls and soft/muddy soils);
- The installation of perched aquifer nested monitoring wells within the Spill Area and Former Fumigant Mixing Area was eliminated based upon the determined vertical distribution of chemicals within the perched aquifer and the relative perched aquifer thickness;
- Additional perched zone monitoring wells MW-3S, MW-4 (dry well), MW-5 and MW-6 were installed to provide further data on the extent of COPCs within the perched groundwater system;
- Perched groundwater sampling from existing extraction Well #9 was added to provide additional data on COPC concentrations in perched groundwater beneath the Former Fumigant Mixing Area;
- Additional geophysical surveying and sampling activities related to two empty drum burial sites in Field 60; and

- Soil samples collected in the excavation pit soil natural attenuation area in Field 8.
- Additional soil sampling was conducted in the Former Fumigant Storage Area to better define the extent of high concentrations of COPCs and to locate extraction wells for the Phytoremediation Treatability Investigation. Eight extraction wells will eventually be installed for the Treatability Investigation, one of which has been installed (EW-1) as of the date of this report.
- EPA's consultant, ICF Kaiser, conducted oversight sampling in November 1997. Two soil vapor samples were collected, and split monitoring well water samples were obtained from the Kunia Well, the new Basal Well, and perched aquifer well MW-6. Results are provided in Appendix K.

Based upon the site conditions and chemical data, EPA approved the task modifications described above.

## 2.2 Soils Operable Unit

### 2.2.1 Rationale and Approach

The soils operable unit is defined in the Work Plan to include surficial and vadose zone soils in the Kunia Village Area and soils associated with Other Potential Source Areas. Sampling performed in these areas are described separately in this section. The objectives of soil sampling in surficial and vadose zone soils were as follows:

- Surficial soils were sampled to assess potential human health risks associated with exposure risks related to direct contact, volatilization, dust generation, and/or surface runoff. The thickness of the surface layer is defined in the Work Plan as 5 feet based on the manner in which these pathways are evaluated.
- The deeper vadose zone soil sampling was performed to determine if any COPCs were present at concentrations which pose an unacceptable risk via leaching to the perched groundwater and to provide information for remedy selection, if determined to be necessary and appropriate.

In order to meet these objectives the DQOs process conducted in the Work Plan was applied quantitatively to the soil sampling program for the Former Fumigant Storage Area, Former Fumigant Mixing Area and the Kunia Well Spill Area. The quantitative approach applied statistics to design the most efficient field investigation for soils to control the probability of making an incorrect decision. A qualitative approach or subjective sampling approach was used to design the sampling of soils for the other potential source areas to access if COPCs exist which pose an unacceptable health exposure or environmental risk. The judgmental sampling approach was applied in the other potential source areas because it is considered the most appropriate and efficient for satisfying the specific field investigation objectives detailed in the Work Plan.

### 2.2.2 General Description of Procedures

The RI field investigation program included sampling and analysis of near surface soils and soils located throughout the full depth of the vadose zone (soils above the perched groundwater zone). Data collected during the soil investigation were utilized to evaluate the stratigraphy beneath the site, assess the lateral and vertical extent of chemicals within surface and vadose zone soils, and determine general physical soil properties (e.g., grain size, soil moisture, bulk density, specific gravity and organic carbon content). Soil investigation activities were conducted in accessible portions of the Kunia Village Area and in the Other Potential Source Areas. The sampling methods used to collect soil samples for chemical and physical analyses are described below.

Soil boring and sample collection for chemical analyses was conducted using a Strataprobe, direct push technology drilling system as described in the Strataprobe Operating Procedures provided in Appendix A of the FSP (Golder 1996a). The Strataprobe system is a rugged, lightweight, hydraulic drive point system mounted on a one ton pickup truck. Samples were collected using a retractable piston sampler which is comprised of a standard spilt spoon with internal stainless steel sleeves and piston assembly driven by the Strataprobe. Upon reaching the desired depth, the piston is removed, and the sampler is advanced into the soil two feet as the piston retracts. After removing the split spoon, the sample sleeves were extracted. A plastic cap with protective Teflon® film was used to seal the sleeve ends. A portion of each collected sample was retained by Golder's field hydrogeologist for geologic logging. Field logs of the borings were prepared in accordance with the Unified Soil Classification System (USCS) standards and classified according with Golder Associates Technical Procedures TP 1.2-5 "Drilling, Sampling and Logging of Soils." Strataprobe boreholes were abandoned using bentonite clay pellets.

Several of the boundary definition sampling locations and samples collected in the Former Fumigant Mixing Area were located in areas inaccessible with the Strataprobe rig. A stainless steel hand auger and drive sampler were used to collect samples from these locations. The borehole was advanced using the hand auger until the desired sample interval was reached. A drive sampler lined with brass sampling sleeves was then driven into the soil. The sleeves were then extracted and sealed on both ends with plastic caps and protective Teflon® film.

All samples were labeled and held in a chilled ice chest or sample refrigerator until being transported, via overnight delivery, to the laboratory under chain-of-custody procedures. Evidence seals were placed on each ice chest containing samples.

Sampling equipment was decontaminated between samples using a non-phosphate detergent wash, double tap water rinse, and final deionized water rinse. The auger drill rig was steam cleaned between each monitoring well borehole.

Soil samples in the near-surface zone were collected at depths of 0.5, 2, and 5 feet below ground surface (bgs). Because the split spoon sampler is 2 feet in length the actual sampling intervals were 0 - 2ft, 2 - 4ft, and 4 - 6ft. Because of the shallow depth to the

perched groundwater in the Former Fumigant Mixing Area, soil samples were collected at the 0 - 2 ft and 2 - 4 ft depth intervals only. For subsurface soils (vadose zone), samples were collected at 0.5, 2, 5, 10, 15, and 25 feet or until the top of the perched aquifer was intercepted (the perched aquifer was consistently intercepted at depths less than 25 feet). Both near-surface and subsurface soil samples were collected from the boreholes completed within accessible areas of the known source area. The boundary definition boreholes included collection of near-surface samples only.

All soil samples were analyzed for Volatile Organic Compounds (VOCs) by EPA Method 8260 (which included EDB and DBCP compounds). A subset of 10% (20% in the Former Fumigant Storage Areas) of these samples were also analyzed for the full COPC list of compounds which includes: VOCs (EPA Method 8260), TPH-diesel (EPA Method 8015M), Lindane, Toxaphene, and Heptachlor (EPA Method 8080), Bromacil and Diuron (EPA Method 632), Ametryn (EPA Method 619), and Fenamiphos (EPA Method 8141). Both soil and water samples collected prior to February of 1998 were analyzed by Ceimic Corporation located in San Diego, California. Ceimic closed their San Diego laboratory in February 1998, after which the contract laboratory for the project was changed to Sequoia Analytical in Petaluma, California who subcontracted Methods 619, 632 and 8141 analyses to North Coast Laboratory in Arcata, California. Contract laboratories were audited by Golder Associate's chemist and approved for use during the Remedial Investigation by EPA.

RI sampling and analysis were completed in accordance with the Del Monte Corporation (Oahu Plantation) Superfund Site Quality Assurance Project Plan (QAPP) (Golder, 1996c). The QAPP outlines the policies and procedures necessary for producing data of known and acceptable quality. Part of the QAPP requirements included a performance audit conducted on the contract laboratories by Golder's chemist prior to the start of analytical work. The performance audit included the submittal of blind samples of known composition to the laboratory and an onsite evaluation of the laboratory for compliance with the QAPP procedures. No quality assurance discrepancies were noted during the performance audits.

Soil samples were also collected for analysis of physical parameters during drilling of monitoring wells MW-1, MW-2 and MW-3 (monitoring well drilling is discussed in Section 2.4.1.3). Soil sampling for physical parameters was conducted using a Mobile Drill B-61 auger drilling rig and 2-inch diameter split spoon sampler lined with brass sleeves. Samples were collected from approximate depths of 2, 5, 10, 25, and 35 feet bgs. Soil physical parameters included bulk density, specific gravity, organic matter content, grain size distribution including hydrometer testing, porosity, and water content. In addition, Shelby tube samples were collected in the saturated zone of the three monitoring well boreholes for vertical permeability measurements. Physical testing was performed by Golder Associates Inc.'s geotechnical laboratory in Redmond, Washington. A summary table of all samples collected and related physical analyses performed is provided in Appendix C.

Boring logs of all Strataprobe and monitoring well boreholes in the Kunia Village Area are included in Appendix B. Also, Appendix B includes borehole logs for borings completed in the Former Fumigant Storage Area in Field 32. Boring logs were not prepared and are not included for all other borings which generally involved the collection of only 1 or 2 samples and were less than 10 feet in depth.

The methods described above were used for soil sample collection throughout both the Known Source Areas and the Other Potential Source Areas. The following sections describe soil sampling completed in each of these areas.

### 2.2.3 Kunia Village Area

The Kunia Village Area consists of the Kunia Well Spill, Former Fumigant Storage and Former Fumigant Mixing Areas (Known Source Areas). Figure 2-1 depicts the Kunia Village Area and the three subareas. The three subareas were preliminarily defined in the Work Plan using previous environmental sampling, historical photographs and interviews with previous DMC employees. The RI Work Plan (ICF 1997) includes a statistically based soil sampling program consisting of a fixed number of soil borings at the vertices of a triangular grid. The layout of soil borings is designed to cover the entire suspected area of each of the three known source areas. In addition, six (6) boundary definition borings were located around the perimeter of each known source area. Each borehole was given a unique identifier (B-1 through B-45).

#### 2.2.3.1 Kunia Spill Area

A total of nine boreholes were completed within the Kunia Spill Area. Based upon the triangular grid format, boreholes where spaced approximately 35 feet apart. Several deviations were required from an exact triangular grid due to various site features (e.g., underground utilities, Kunia well piping, and topography). In addition, six boundary definition boreholes were completed to a depth of five feet around the Kunia Spill Area perimeter. Figure 2-2a depicts the location of all completed borehole locations.

The perched groundwater was intercepted at a depth of approximately 23 feet below ground surface (bgs) in the Kunia Spill Area limiting soil sampling to a depth of 25 feet or less. Soil samples for physical analysis were collected during the drilling of monitoring well MW-1.

In order to evaluate chemical concentrations present in the soil air space, soil vapor sampling was conducted at a depth of 11 feet bgs in boreholes B-7 and B-8. These boreholes were selected for soil vapor sampling because they were located in the area where elevated EDB and DBCP compounds were historically observed in subsurface soils. Soil vapor samples were obtained using the Strataprobe soil vapor sampling procedures as referenced in the FSP (Golder 1996a). A six liter Summa canister was used to collect the soil vapor samples as described in Golder Technical procedure "Ambient Air/Soil Vapor Sampling for Chemical Analysis, TP-1.2-25." Soil vapor samples were analyzed for VOCs by EPA Method TO14, at Air Toxics Ltd., Folsom, California.

2.2.3.2 Former Fumigant Storage Area

A total of eight boreholes were completed initially within the Former Fumigant Storage Area. The ninth borehole location as proposed in the FSP was not accessible due to the presence of a near vertical cliff and the pit area. The perched groundwater was intercepted at depths ranging from 25 feet bgs in B-28 to 3 feet bgs in B-33. The FSP required soil sampling only in the unsaturated (vadose) zone. In consideration of the limited depth of vadose zone, samples were collected from both the vadose zone plus one additional sample was collected at the first prescribed sampling interval that was in the saturated zone. For example, the perched aquifer was intercepted at a depth of 11 feet in borehole B-27; therefore, soil samples were collected at 0.5, 2, 5, 10, and 15 feet bgs. In addition, six boundary definition boreholes were completed around the perimeter of the Former Fumigant Storage Area.

In order to evaluate chemicals concentrations present in the soil airspace, soil vapor sampling was conducted at a depth of 11 feet bgs in boreholes B-27 and B-28. These boreholes were selected for soil vapor sampling because they were located in the area where elevated EDB and DBCP compounds were historically observed in subsurface soils. Soil vapor samples were obtained using the Strataprobe soil vapor sampling procedures as referenced in the FSP (Golder 1996a). A six liter Summa canister was used to collect the soil vapor samples as described in Golder Technical procedure "Ambient Air/Soil Vapor Sampling for Chemical Analysis, TP-1.2-25." Soil vapor samples were analyzed for VOCs by EPA Method TO14, at Air Toxics Ltd., Folsom, California.

2.2.3.3 Additional Soil Sampling in the Former Fumigant Storage Area

During July and August of 1998, nine additional boreholes were drilled and sampled in the Former Fumigant Storage Area. The additional boreholes were drilled to further characterize the extent of COPCs detected in deeper soils (i.e. soils below 25 feet) located within the Former Fumigant Storage Area. The boreholes also provided data for the design and location of perched groundwater extraction wells associated with the phytoremediation Treatability Investigation (TI). The TI is being performed at the DMC (Oahu Plantation) Superfund Site by DMFP/Golder under the United Stated Department of Agriculture-Cooperative State Research, Evaluation and Education Service (USDA-CSREES) and the United States Army Environmental Center (USAEC).

The TI is a phased and integrated approach to evaluate pump and phytoremediation methods for source removal, phytoremediation treatment, and hydraulic containment of COPCs in investigative derived soils and perched groundwater from the Former Fumigant Storage Area. The objectives, rationale and approach for each phase of the Treatability Investigation were presented to EPA in TI Technical Memoranda 98-1,-2,-3 and -4 (DMFP 1998a,b,c,d).

The Treatability Investigation boreholes were drilled using a Mobil Drill B-61 hollow stem auger. Soil samples were collected from each borehole using a split spoon sampler lined with 6-inch brass sleeves. The nine boreholes were located in portions of the Former Fumigant Storage Area where historical data indicated that potentially elevated

levels of COPCs were present or in areas where historical data was absent. Figure 2-2b depicts the location of the Treatability Investigation boreholes. Two additional boreholes were drilled in October 1998. These will be discussed in the Feasibility Study report.

Shallow vadose zone soils previously investigated during the RI were not found to contain COPCs (discussed in Chapter 4). In addition, historical data and data collected during the drilling of monitoring wells MW-3 and MW-3s indicated that elevated levels of COPCs in the Former Fumigant Storage Area were typically detected at depths of 30 feet and greater. As such, samples collected during TI drilling started at 25 to 30 feet bgs. Samples were generally collected every 10 feet until encountering the weathered basalt. Large basalt boulders limited drilling depths in boreholes TB-5 and TB-8 to approximately 45 feet. Samples were collected at five-foot intervals at selected depths of boreholes where dense non-aqueous phase liquids (DNAPLs) potentially could be encountered. DNAPLs were not encountered in any of the boreholes. Most of the samples collected were saturated as the perched groundwater was typically intercepted at 35 to 45 feet bgs. All TI borehole soil samples were analyzed for volatile organic compounds by EPA Method 8260.

#### 2.2.3.4 Former Fumigant Mixing Area

Proposed drilling locations in the Former Fumigant Mixing Area were within the boundaries of an area where contaminated soils had been excavated in 1993. Soils were reported to have been excavated to a maximum depth of 60 feet and approximately 15 feet below the water table. Although some clean backfill material was placed in the excavated area subsequent to the 1983 excavation, a large surface depression or "pit area" still remains in the Former Fumigant Mixing Area.

The Former Fumigant Mixing Area was inundated with water during all of 1997. Water within the pit area was determined to be reflective of the perched groundwater. This determination was based upon the similarity of the pit water elevation and the elevation of the perched groundwater measured in piezometers located near the pit. The elevated water within the pit prevented sampling of unsaturated soils within the Former Fumigant Mixing Area. The six boundary definition boreholes, surrounding the pit area were completed during the first phase of RI field work.

Justification for eliminating sampling in the Former Fumigant Mixing Area was originally presented to Region IX EPA in Technical Memorandum 97-5 (Golder 1997a). EPA provided approval for eliminating soil sampling in the Former Fumigant Mixing Area in a letter dated December 10, 1997. In place of soil sampling, EPA and DMFP agreed to include groundwater sampling of the existing extraction well #9 which is installed within the Former Fumigant Mixing Area.

However, during 1998 drought conditions in Hawaii resulted in the pit area becoming completely dewatered. As a result, EPA and DMFP agreed to supersede the decision made based upon Technical Memorandum 97-5 and conduct soil sampling in the unsaturated soils within the Former Fumigant Mixing Area.

In accordance with the FSP (Golder 1996a), nine boreholes were distributed in a triangular grid pattern over the Former Fumigant Mixing Area (Figure 2-2). Strataprobe access into the Former Fumigant Mixing Area was not possible due to the steep side walls and soft pit floor; therefore, soil samples were collected from each borehole using a stainless steel hand auger and drive sampler. Near surface vadose zone soil samples were collected from the depth intervals of 0 - 2 ft and 2 - 4 ft. Soils were saturated below about 4 ft. Sample analyses were conducted as described in Section 2.2.2.

### 2.2.4 Other Potential Source Areas

#### 2.2.4.1 Perimeter Areas of the Kunia Village Area

The Work Plan identified areas where empty drums appeared to have been stored around the perimeter of the Kunia Village Area. One area is on the west side of the maintenance building (Figure 2-3). The Strataprobe drilling/soil sampling system as described above was used to collect one soil sample (PA-4) at a depth of five feet from this area. The sample was analyzed for volatile organic compounds (VOCs) by EPA Method 8260 and for TPH-diesel using EPA Method 8015 Modified.

The second area is north of the Former Fumigant Storage Area (Figure 2-3). The Strataprobe drilling method was used to collect a soil sample at a depth of five feet from three locations (PA-1, PA-2, and PA-3) within this area. Each sample was analyzed for VOC's and TPH-diesel. In addition, one sample was analyzed for the full COPC list of compounds.

#### 2.2.4.2 Former Fumigant Storage Area Near Field 32

Between the early 1940's and 1955 a soil fumigant cylinder and drum storage area was operated by DMC in a pineapple field area located near the current pineapple Field 32. The Former Fumigant Storage Area near Field 32 was approximately located based upon preliminary reconnaissance by a former DMC truck driver using maps from a previous 104(e) response (Figure 2-4). The area encompasses approximately 90 feet by 110 feet. There are no records of soil fumigant spills occurring in this area.

The Work Plan identified that the completion of nine soil borings in this area would provide sufficient confidence that VOCs or other COPCs will be detected in this area if they are present. The nine boreholes were completed in this area on a triangular grid with approximately 33-foot spacing between holes. Soil samples were collected using the Strataprobe from depths of 0.5, 2, 4, 10, 15, and 25 feet bgs. All samples were analyzed for VOCs by EPA Method 8260 and a subset of approximately 20% were analyzed for the full COPC list. Boring logs for these boreholes are included in Appendix B.

#### 2.2.4.3 Empty Fumigant Drum Burial Sites

In the Work Plan five of the 22 identified empty drum burial sites were selected to provide chemical data on the absence or presence of COPCs to evaluate if these sites

pose unacceptable environmental risks that require further characterization. The sampling sites were selected based upon accessibility, geographic distribution, and to sample the potentially worst case scenario in Field 60 where 8 of the 22 sites are located. Judgmental sampling activities were used to sample soils in the most likely areas where chemicals may be detected related to previous site activities. The five sites selected for investigation include:

- Empty Drum Burial Site behind the Poamoho Crateyard;
- Empty Drum Burial Site in Field F-90A (previously designated as Field 94);
- Empty Drum Burial Site in Field F-60;
- Empty Drum Burial Site in Field F-31 (Field F-31 was substituted for Field F-08 for access reasons after receiving EPA approval); and
- Empty Drum Burial Site in Field F-32.

The approximate location of the 22 empty drum burial sites, including the five sites investigated, are shown in Figure 2-4. The sites were approximately located in the field using maps provided by EPA based upon preliminary reconnaissance by DMFP. Geophysical equipment was used in order to further delineate the boundaries of the five empty drum burial sites. Appendix D contains a detailed summary of the geophysical methods used to delineate the empty drum burial sites and survey results.

Three boreholes were drilled at each empty drum burial site in the area identified by the geophysical surveys to have the highest potential to contain buried material. Borehole drilling and soil sampling were conducted using the Strataprobe drilling system. All soil samples collected from empty drum burial sites were analyzed for VOC's by EPA Method 8260. A subset of 50% of soil samples were also analyzed for Lindane, Toxaphene, Heptachlor (EPA Method 8080), Bromacil and Diuron (EPA Method 632), Ametryn (EPA Method 619), and Fenamiphos (EPA Method 8141). In addition, 10% of the soil samples were also analyzed for TPH-diesel using EPA Method 8015 Modified.

#### 2.2.4.3.1 Geophysical Survey Results and Soil Sample Collection

##### 2.2.4.3.1.1 Empty Drum Burial Site Behind the Poamoho Crateyard

The location of the empty drum burial site behind the Poamoho Crateyard is shown on Figure 2-4. Based upon the geophysical surveys, this site had significant magnetic anomalies concentrated in the northeast section and along the western boundary (Figure 2-5). The anomalies in the northeast section are interpreted to be related to buried debris and correspond with the reported location of the buried empty drums. The anomalies along the western boundary correspond with surface debris.

As can be seen on Figure 2-5, the high anomaly area in the empty drum burial site behind Poamoho Crateyard was linear in shape and measured about 25 ft by 65 ft. Three borehole locations were selected evenly spaced in a line along the center area of the high anomaly. Metal debris was encountered during drilling at a depth of four to six feet bgs. The buried debris was no longer encountered below a depth of seven feet.

As such, a soil sample was collected from directly beneath the buried material at a depth interval of seven to nine feet, and a second sample was collected five feet below at a depth interval of 12 to 14 feet bgs. Two soil samples were collected from each of the three boreholes for chemical analysis.

Although not specified by the FSP, one soil gas sample was collected from each of the three boreholes. The soil gas samples were collected at the base of the buried debris (i.e., 6 ft bgs) using the Strataprobe extractable tip soil gas probe and a 6-Liter Summa Canister in accordance with Golder Technical Procedure TP-1.2-25 "Ambient Air/Soil Vapor Sampling for Chemical Analysis."

2.2.4.3.1.2 Empty Drum Burial Site in Field 90A

The location of the empty drum burial site in Field 90A (previously designated as Field 94) is shown on Figure 2-4. The geophysics electromagnetic (EM) survey is presented on Figure 2-6. The largest EM anomaly corresponds with the location of the largest magnetic anomaly in the central section of the site; an area approximately 20 feet by 20 feet. This area was selected to be the most likely location of the buried empty drums.

Three borehole locations were selected in a triangle configuration based on the centered portion of the anomaly (Figure 2-6). Through a process of test probing with the Strataprobe, it was discovered that in the area where empty drums appear to have been buried, the soil was uncompacted and very easily probed to a depth of 5 to 7 feet. In addition, some debris (blue metallic flakes) was observed in soil samples collected at a depth of 3 to 5 feet bgs. Based on this information, two soil samples were collected from each borehole - one just below the base of the burial site and one five feet beneath the base.

2.2.4.3.1.3 Empty Drum Burial Site in Field 60

Eight of the 22 empty drum burial sites are located in Field 60. Geophysical surveys were performed in March 1997, at two empty drum sites in Field 60, located within Blocks 9 and 10 (Figure 2-7a). A dirt road is located along the northern border of the site and two shallow depressions are located in the central and eastern sections of the site (Figures 2-7b and 2-7c).

The geophysical surveys detected moderate anomalies in the areas which corresponded with the visible surface depressions. The surface depression located in the eastern portion of site was larger, as such, Strataprobe drilling was utilized to further investigate this area Figure 2-7c). Using similar test probing methods as was used in Field 90A, it was estimated that the burial site was relatively small (15 ft by 15 ft) and had an approximate maximum depth of 11 feet. Buried debris was observed in soil samples collected at a depth of 5 to 7 feet bgs. Three boreholes were completed in a triangular configuration centered on the anomaly/surface depression (Figure 2-7c). Two soil samples were collected from each borehole for chemical analysis - one at the base of the burial site and one five feet below the base.

2.2.4.3.1.4 Empty Drum Burial Site in Field 31

The location of the empty drum burial site in Field 31 is shown on Figure 2-4. Dirt roads cross diagonally north to south through the site and along the eastern border. The survey stake marking the approximate location of the buried empty drums was located along the east central section of the survey area (Figure 2-8). The geophysical survey conducted in this area detected only moderate anomalies (see Appendix D).

Several test probes and soil samples for observation were collected in the areas where anomalies were observed during the geophysical survey. Additional test probing was conducted in the area which was staked based on historical records. No debris or other evidence was observed to confirm the location of an empty buried drum site in this area; as such, no soil samples were collected from Field F-31 for chemical analysis.

2.2.4.3.1.5 Empty Drum Burial Site in Field 32

The location of the empty drum burial site in Field 32 is shown on Figure 2-4. Figure 2-9 depicts the EM survey in Field 32. Similar to Field 31, only moderate anomalies were detected during the geophysical surveys.

Several test probes were conducted and soil samples collected for observation in the areas where anomalies were observed. Additional test probing was conducted in the area which was staked based on historical records. No debris or other evidence was observed to confirm the location of a buried empty drum site in this area; as such, no soil samples were collected from Field F-32 for chemical analysis.

2.2.4.3.1.6 Additional Empty Drum Burial Sites

In compliance with an EPA requirement, two additional empty drum burial sites in Field 60 were investigated in May 1998. RI Technical Memorandum 98-1 rev. 1 (Golder 1998) details the rationale, approach and field procedures used for environmental sampling at the additional empty drum burial sites. EPA approval of TM 98-1 rev. 1 was received in a letter dated March 18, 1998.

In an attempt to positively identify two additional empty drum burial sites in Field 60, geophysical surveying was performed at four possible sites located in Blocks 4, 5, 6 and the south end of blocks 9 and 10 of Field 60 (Figure 2-7a). Appendix D details the results of these additional geophysical investigations. In summary, no indications of locating empty drum burial site(s) were observed in Blocks 4, 5, and 6. The geophysical survey did detect a moderate magnitude anomaly in the southwest corner of Blocks 9 and 10 (Figure 2-7d). No other moderate sized anomalies were observed during the May-98 geophysical survey.

As described in Section 2.2.4.3.1.3, during the March-97 survey moderate size anomalies were observed corresponding with two surface depressions located in Blocks 9 and 10, and only one of these depressions was sampled (Sampling Location 1 on Figure 2-7a). During the May-98 investigation the second depression and the moderate size anomaly located in the southwest corner of Blocks 9 and 10 were further investigated using the

Strataprobe drilling and sampling methods describe above. These two additional empty drum burial sites are given the designation of Sampling Location 2 and 3 on Figure 2-7a.

Three boreholes were drilled at each of the two additional empty drum burial sites. Samples were collected from each borehole at the base of the buried material and five feet below the base. Using probing methods described previously the base of the buried material was located at six to eight feet below ground and each of the empty drum burial sites were approximately 10 ft by 10 ft in size. Samples collected within the burial areas were observed to contain metal, paint chips, and plastic. Figures 2-7b and 2-7d depict the borehole locations at Field 60 empty drum burial sites.

#### 2.2.4.4 Former Underground Storage Tank (USTs) Sites

Three former underground storage tank (UST) sites were investigated as part of the Remedial Investigation. UST investigation included collection of soil samples in the areas where USTs had previously been located. The former UST sites were permanently closed by removal from the ground. UST removal activities were performed prior to the HDOH requirement for submittal of closure reports implemented in 1987. Figure 2-4 depicts the location of the former UST sites. The sampling conducted was designed to augment previous sampling at the sites and document UST closure. Soil samples were collected using the Strataprobe soil sampling methods described in Section 2.2 above.

All soil samples collected at former UST sites were analyzed for TPH-Diesel using EPA Method 8015 Modified. In addition, TPH-Oil was quantitated at the location of the Maintenance Building Dip Pan. TPH-Gas was quantitated at the former UST location in the Poamoho Crateyard. Soil samples with a TPH concentration in excess of 100 mg/kg were also analyzed for BTEX using EPA Method 8020, for PAHs by EPA Method 8310, and cadmium and lead by ICP. Sampling conducted at each of the three sites is described below.

*Poamoho Crateyard* - Two former 6,000 gallon USTs that contained diesel fuel and gasoline were located in the Poamoho Crateyard. Both tanks were removed in 1987. According to DMC personnel, no olfactory or visual signs of petroleum constituents were observed during tank removal. The sampling augmented previous soil samples taken at the end of each tank in 1995. The previous samples did not contain detectable Total Petroleum Hydrocarbons -Gas (TPH-Gas) or TPH-Diesel. A closure report covering the former UST sites in the Poamoho Crateyard, Field 9 Booster Pump, and the Equipment Shop Dip Pan was submitted to EPA and HDOH in August 1995, however, the closure report was not accepted by the HDOH resulting in additional sampling requirements.

A total of five soil borings were completed in the area of the two former USTs. One soil boring was advanced in the center of each former tank location and sampled one foot below the previous tank's base. A second sample was collected five below the base. The tanks' base were determined in the field based upon the lithologic change from loose fill to dense native soil. The tank base was determined to be 11 feet bgs for the former gasoline tank and 10 feet bgs for the former diesel tank. Three additional soil borings

were advanced to collect soil samples at a depth of five feet bgs to address potential leakage from associated fuel line piping. Figure 2-10 depicts the Poamoho Crateyard former UST sampling locations.

*Field 9 Booster Pump* - One borehole was advanced in an area adjacent to the former 2,000 gallon diesel tank which was removed in 1986. In accordance with the FSP a soil sample was collected at the approximate depth of the former tank excavation (10 feet) and at 15 feet bgs. The soil sample collected at 15 feet appeared stained and contained a petroleum odor. In order to determine the vertical extent of petroleum impact, two additional samples were collected from the borehole at depths of 20 feet and 24 feet bgs. Figure 2-11 depicts the Field 9 UST sampling location.
*Maintenance Building Dip Pan (Kunia Baseyard)* - A single boring was advanced to collect soil samples at five and 10 feet bgs at the location of a former 200 gallon used oil tank which was removed in 1985. Figure 2-3 depicts the location of the former UST sample location.

2.2.4.5 Methyl Bromide Cylinder Burial Site in Field 71

The RI Work Plan and FSP describe a buried cylinder containing approximately 43.5 pounds of methyl bromide which was reportedly buried in Field 71. Based on site maps provided by DMC to the EPA the approximate location of the buried drum site was staked by DMFP personnel. Geophysical survey equipment was used in an attempt to locate the precise location of the buried cylinder.

The location of Field 71 is shown on Figure 2-4. Golder established the geophysical survey control grid in a 60-foot by 100-foot area located in a pineapple field. A dirt road is located along the northern border of the site. The survey stake marking the approximate location of the methyl bromide cylinder was located in the center of the site (Figure 2-12a).

The magnetic vertical gradient data are displayed in Figure 2-12a. This site has two small magnetic anomalies (less than +/- 50 nT/m) located along the eastern and northern edges of the site. These anomalies, interpreted as being the most likely location of the methyl bromide cylinder, were marked with stakes.

The conductivity data are displayed in Figure 2-12b. The terrain conductivity values range from 13 to 14 mS/m, and no major anomalies are evident in the data. The lack of a conductivity anomaly corresponding to the location of the magnetic anomalies suggests that there may only be minor amounts of metal present in the areas with the magnetic anomalies.

Although no definitive burial area was located using the geophysical survey, backhoe exploratory pits were excavated in the areas where the two minor magnetic anomalies were identified. The first backhoe pit was dug 14ft by 12ft wide and 8ft deep. The backhoe pit at the second anomaly was dug 8ft by 10ft wide and 8ft deep. A third pit was dug 8ft by 8ft by 8ft in the area staked based upon historical data. Figure 2-12a depicts the backhoe exploration areas. Golder field personnel inspected the excavated

soil and the excavation pits for any indication of buried debris. A Microtip photo ionization detector was also used to screen the soil as it was excavated for any indication of volatile organic compounds. No indications of the buried methyl bromide cylinder were identified in any of the excavation pits; therefore, no soil samples were collected for chemical analysis.

2.2.4.6 Current Soil Fumigant Storage Facility

The Current Soil Fumigant Storage Facility, a concrete-lined above ground product storage facility, was visually inspected by EPA and Golder personnel during a site tour on April 29, 1997. In accordance with the Work Plan (ICF 1997), no sampling is required at the facility, since there is no evidence that a release of hazardous substances has occurred at the facility.

Golder personnel further inspected the Current Soil Fumigant Storage Facility on August 22, 1997 and conducted a photographic documentation of the facility (Figures 2-13 a,b,c). The facility contains two 5,000 gallon stainless steel product storage tanks. The tanks currently contain Telone II (which consists of 1,3-dichloropropene). Both tanks are contained in a covered concrete lined containment area and can be visually inspected for cracks, leaks or spills. Dispensing hoses are equipped with vapor return lines. To prevent corrosion, the tanks are equipped with air scrubbers and are inerted with a nitrogen oxide blanket. The tanks are inspected daily by DMFP personnel during routine handling activities. In addition, representatives from Dow Chemical Company perform annual inspections of the Current Soil Fumigant Storage Area. Dow Chemical Company also requires specific safety handling procedures of Telone II which are followed by DMFP personnel.

2.2.4.7 Excavation Pit Soils Natural Attenuation Area in Field 8

Soils excavated from the Kunia Village Area during the 1981 and 1983 soil removal actions were spread in a thin layer over an approximate 20 acre pineapple field area in Field 8 which is located approximately 1,700 feet west of the Kunia Village (Figure 2-4). The area in Field 8 has been cultivated four times since the early 1980's. This was conducted with approval from the State of Hawaii to allow volatilization and natural attenuation to occur. The State's rationale for permitting natural attenuation was that the soil fumigants were still registered for agricultural uses in pineapple fields at that time.

After excavated soils were spread, approximately 20 tons of cow manure per acre was spread onto the area followed by standard land preparation activities. Land preparation activities for the Oahu Plantation have remained unchanged since the early 1980's and consist of subsoiling and disking to effectively till approximately 18 to 24 inches of the upper soil.

Although the excavation pit soils natural attenuation area in Field 8 was not identified as an Other Potential Source Area in the RI/FS Work Plan, EPA requested that data be collected from this area to determine if COPCs were present in vadose zone soils at

concentrations which pose a risk to human health or threat to groundwater. Technical Memorandum 98-1 rev. 1 (Golder 1998) provided EPA with the objectives, rationale and field procedures proposed for sampling in the excavation pit soils natural attenuation area in Field 8. EPA approved the provisions of TM 98-1 rev. 1 in a letter dated March 18, 1998.

Strataprobe drilling and sampling methods were utilized to collect soils samples from nine locations distributed evenly throughout the natural attenuation area in Field 8. Figure 2-14 depicts the nine borehole locations. Soil samples were collected from each of the nine boreholes at the approximate depths of 2 ft, 10 ft and 15 ft bgs. All soil samples were analyzed for VOCs by Method 8260. In addition, 20% of all samples were analyzed for lindane, toxaphene and heptachlor (Method 8081), and ten percent were analyzed for TPH-diesel (Method 8015M).

## 2.3 Surface Water and Sediment

### 2.3.1 Rationale and Approach

The surface water and sediments are associated with the ephemeral gulch northeast of the Kunia Village Area which eventually drains into the Poliwai Gulch, and the smaller ravine just to the southeast of the Kunia Village Area (Figure 2-15). The focus of the surface water and sediment investigation is to determine if potential residual contamination from stormwater runoff and eroded soils are present in the ravine and gulch sediment/soil or surface water at concentrations that pose an unacceptable risk to human health via exposure pathways defined in the Work Plan.

Data required to determine whether concentrations in the sediment/soil or surface water in the northeast gulch and adjacent smaller ravine are acceptable include:

- Measurement of the COPCs in the sediment/soils along the gulch and drainages where the highest probability of runoff from the upgradient sources occurred;
- Measurement of the COPCs in surface water, when water is flowing in the gulch; and
- Measurement of the COPCs in the soil media and perched groundwater in the upgradient source areas are also needed, but this was conducted under the soils and groundwater investigation in the Kunia Village Area.

In order to collect data to meet these objectives, a judgmental sampling approach was used to select sampling locations in the gulch and ravine most likely to receive runoff from upgradient source areas. Two primary types of data collection methods were conducted.

- Surface and subsurface sediment/soil samples in drainage areas of the gulch and ravine to assess if COPCc are present in the surface layer; and
- Surface water samples during or following a storm event to assess the flowing water quality conditions.

### 2.3.2 Sampling Locations

Figure 2-15 depicts all of the Surface Water and Sediment Sampling Locations. Locations were selected based upon historical and present topography, likely areas of runoff, locations of the upgradient source areas, location of other proposed soil borings, and historical surface concentrations as follows:

- Two surface/near surface locations were sampled at depths of 0.5, 2 and 5 feet bgs in the area downgradient of the Kunia Well Spill Area. The two locations were selected to be representative of areas most likely to receive runoff toward the southeast down the existing ravine. One of the selected locations coincided with Strataprobe borehole B-2. The other location is identified as R-1 on Figure 2-15.
- Two surface/near surface locations were sampled at depths of 0.5, 2 and 5 feet bgs in the area most likely to receive runoff from the Former Fumigant Mixing and Storage Area. The two areas selected to most likely receive runoff from these areas coincided with Strataprobe boreholes B-26 and B-29.
- Five sediment samples were collected from along the northeast gulch in the areas most likely to have received drainage (i.e., S-1 through S-5). Three soil samples were collected within the ravine southeast of the Kunia Spill Area (i.e., S-6 through S-8).
- Three surface water samples were collected from the northeast intermittent stream gulch. One sample (SW-1) was located upgradient of the site, one sample (SW-2) was directly downgradient of the Former Fumigant Storage Areas, and the third sample (SW-3) was collected from surface water which was observed flowing into the gulch from a westerly direction at a location downgradient of the Former Fumigant Storage and Mixing Areas. Surface water was not observed entering or flowing in the ravine southeast of the Kunia Spill Area. The surface water samples were collected on March 17, 1997 during a heavy rainfall (1.7 inches). Field personnel observed that water only flows in the gulch during moderate to heavy rainfall.

### 2.3.3 Sampling Methods

Near surface soil and sediment samples were collected from discrete depth intervals below the surface. Overlying soil was removed by a shovel or hand auger. The samples were then obtained using a drive tube sampler lined with brass sampling sleeves. The drive sampler was driven with a slide hammer, and the inner sleeve removed, the ends were covered with Teflon, capped on both ends, labeled, and placed in an ice chest until being transported to the laboratory. Hand sampling was conducted in accordance with Golder Technical Procedure TP 1.2-18 "Sampling Surface Soil for Chemical Analysis." Sampling locations that coincided with borehole locations were sampled using the Strataprobe drilling and sampling methods described in Section 2.2 above.

Surface water samples were collected from the intermittent stream gulch during a heavy rain storm. Surface water sample bottles were filled directly from the surface water

flow. Following sample collection, sample bottles were labeled, sealed and placed in a cooler until being transported to the laboratory.

### 2.3.4 Sample Analysis

Near-surface soil samples and sediment samples were analyzed for VOCs including EDB and DBCP (EPA Method 8260). A subset of 10% of these samples were also analyzed for TPH-diesel (EPA Method 8015M), lindane, toxaphene, and heptachlor (EPA Method 8080), bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141). All surface water samples were analyzed for VOCs (EPA Method 8260), TPH-diesel (EPA Method 8015M), lindane, toxaphene, and heptachlor (EPA Method 8080), PAHs (EPA Method 8310) and EDB/DBCP (EPA Method 504.1). Analysis for bromacil and diuron (EPA Method 632), ametryn (EPA Method 619), and fenamiphos (EPA Method 8141) were conducted on a single surface water sample (SW-2) selected in the field at a location most likely to receive runoff from the Kunia Village Area. Table A-1 in Appendix A provides a summary of all samples collected and associated analyses performed. Analytical results are discussed in Chapter 4 of this report.

## 2.4 Groundwater Operable Unit

### 2.4.1 Perched Water Bearing Zone

#### 2.4.1.1 Rationale and Approach

EDB and DBCP have historically been detected above their respective MCLs in the perched water-bearing zone in the vicinity of the Kunia Village Area. The primary concern related to the residual COPCs is whether they pose an unacceptable risk to human health via the exposure pathways defined in the Work Plan, including:

- Transport of COPCs to either surface water via seeps of springs or the basal groundwater by migration through the basalt or through the Kunia Well; and
- Ingestion, dermal contact or inhalation resulting from potential surfacing of perched groundwater in the area.

As indicated in the RI/FS Work Plan (ICF 1997), a judgmental sampling approach was used for the perched aquifer investigation. The lateral and vertical extent of the COPCs within the perched water-bearing zone needed to be defined to address the potential impact to the basal aquifer and surface water exposure pathways and the resulting risk.

Data collected to address these issues for the perched zone aquifer included measurements of the COPCs to assess the lateral and vertical distribution of chemicals in the perched water-bearing zone and measurements needed to assess the hydraulic characteristics and hydrogeology of the perched water-bearing zone including grain size distribution, organic carbon content, permeability, groundwater flow direction and gradient.

In order to provide these data the following methods of data collection were used during the study:

- Temporary piezometers to define the boundaries of the perched water-bearing zone, hydraulic properties and the lateral extent of VOCs (Method 8260), and EDB and DBCP (Method 504); and
- Boreholes, Hydropunch sampling and monitoring wells to define the vertical extent of the perched water-bearing zone, hydraulic properties, and the vertical distribution of COPCs.

The data collected was used to assess the areal and vertical extent of the sources, and the potential pathways relevant to migration of COPCs to the basal aquifer and surface water pathways. Sampling was used to determine if COPCs are present at concentrations exceeding their respective MCLs or calculated PRGs.

#### 2.4.1.2 Piezometer Installation and Sampling

The RI/FS Work Plan (ICF 1997) and the FSP (Golder 1996a) presented the justification for the selected locations of eight temporary piezometers placed in and around the Kunia Village Area. The overall purpose of the piezometers was to define the boundaries of the perched water-bearing zone, hydraulic properties and the lateral extent of VOCs, and EDB and DBCP. Figure 2-16 presents the piezometer locations.

The piezometers were completed using the Strataprobe drilling and piezometer installation standard operating procedures presented in Appendix A of the FSP. The procedures used are briefly discussed below.

The boreholes were advanced to approximately 20 feet below the depth where the perched water system was intercepted. The perched groundwater was intercepted at fairly shallow depths - 19 to 24 feet bgs in the Kunia Well Spill Area and 3 to 19 feet bgs in the Former Fumigant Storage Area. With the exception of piezometer P-2, a 3-inch diameter probe tip was used to enlarge the borehole. Piezometer P-2 was the first piezometer installed. P-2 was installed in a 2-inch diameter borehole which made installation of the sand pack and bentonite seal difficult due to the small annulus. The clay nature of the soil in this area allowed the piezometers to be installed in open boreholes. A schedule 80 PVC, flush-coupled, one inch diameter well screen with 0.01 inch slots was used in all piezometers. A ten-foot length of screen was used in piezometer P-2. After P-2 was installed the decision was made to use 20-foot screens in all other piezometers due to the shallow depth at which the perched water system was encountered.

A filter pack of Monterey #3 sand was installed to three feet above the top of the screen. Approximately three feet of bentonite pellets were placed immediately above the sand pack. The remainder of the annular space was sealed using a Portland Type I/II cement bentonite grout to within 2 feet of the surface. The surface of the piezometers was completed with a 4-inch square protective steel well monument secured with quickcrete cement. The cement was domed around the base to divert runoff water away from the well. Following well completion, the depth to water in the piezometers was measured

in accordance with Golder Technical Procedure TP 1.4-6 "Technical Procedure for Water Level Measurement." Table 2-1 provides the well piezometer construction details for all eight piezometers. Piezometer construction logs are included in Appendix B.

All piezometers were developed by surging and bailing standing water from each piezometer casing and filter pack. Water quality parameters (pH, temperature, conductivity, and turbidity) were monitored during purging. Purging continued in each piezometer until 5 well volumes had been removed and water quality parameters had stabilized. Piezometer P-8 was bailed dry four times. Following piezometer development, a groundwater sample was collected from each piezometer and analyzed for VOCs (Method 8260) and EDB and DBCP (Method 504). Samples were collected using dedicated disposable bailers.

All perched groundwater from the Kunia Village Area produced during development and sampling was collected in 55-gallon containers and will be treated with carbon adsorption or other alternative methods in accordance with EPA and State requirements.

#### 2.4.1.3 Perched Zone Monitoring Well Drilling

The Work Plan and FSP describe a judgmental sampling approach to optimally design the perched groundwater monitoring program in the Kunia Village Area. In accordance with this approach, three perched zone monitoring wells were installed during the first phase of field investigation. Perched zone monitoring well MW-1 was installed in the central area of the Kunia Well Spill Area, MW-2 was installed just downgradient of the ponded area, and MW-3 was installed in an area of the Former Fumigant Storage Area where elevated levels of COPCs were historically detected in soils. The FSP indicated that MW-2 was to be installed in the center of the Former Fumigant Mixing Area. As discussed in Section 2.2.1.3, the Former Fumigant Mixing Area is typically inundated for most of the year and contained over 10 feet of water during the RI field sampling period. Therefore, EPA provided approval to relocate MW-2 in close proximity and downgradient of the Former Fumigant Mixing Area. In addition, regular sampling of existing perched extraction well no. 9, previously installed in the Former Fumigant Mixing Area, has been added to the perched groundwater monitoring program.

Figure 2-16 depicts the perched zone monitoring well locations. In accordance with the FSP all three monitoring wells were drilled and sampled to the total depth of the perched aquifer. Drilling, sampling and monitoring well construction methods are described below.

An 8-inch diameter borehole was drilled using a Mobile Drill B-61 auger drilling rig. Soil samples were continuously collected in MW-1 using a split spoon sampler. The purpose of continuous sample collection was to identify any potential major changes in lithology within the saprolites. During drilling of MW-1 the saprolites were found to be generally uniform with no distinct boundary zones identified. After receiving EPA approval, the frequency of sampling was reduced to every five feet during drilling of MW-2 and MW-3.

Soil samples for physical analysis were collected at depths of 2, 5, 10, 25 and 35 ft bgs using the split spoon sampler with inner brass sleeves. Physical parameters include bulk density and specific gravity (ASTM D854-83), organic matter content (ASTM D2974), grain size analysis including hydrometer testing (ASTM D-422), porosity, and water content (ASTM D2216-90). In addition, Shelby tube samples were collected in the saturated zone in each of the three monitoring well boreholes for hydraulic conductivity (permeability) measurements. Analysis was conducted in accordance with ASTM D 5084 "Measurement of Hydraulic Conductivity of Soil Porous Media using a Flexible Wall Permeameter." All physical analyses were conducted at Golder Associates Inc.'s Geotechnical Laboratory located in Redmond, Washington, except for the organic matter content which was conducted by Ceimic Corporation.

Samples were collected of the perched groundwater during monitoring well drilling at approximate 20-foot depth intervals using Hydropunch sampling methods. Hydropunch samples were collected by driving a screen point sealed using o-ring connections 2 to 5 ft into the formation beyond the bottom auger bit into undisturbed material. Once the depth had been reached the screen is exposed by pulling back the rods one to two feet. Groundwater flowing passively into the screen was then sampled through the rodbore using a 1/2-inch diameter stainless steel bailer. Hydropunch samples were analyzed for VOCs (Method 8260), and EDB and DBCP (Method 504). The sampler and bailer were disassembled between uses and decontaminated using the procedures presented in Section 6.8 of the FSP (Golder 1996a). Table 2-2 provides a summary of sample types, depths and analyses performed during perched monitoring well drilling.

Auger drilling extended to the start of the weathered basalt rock. In the first perched monitoring well drilled, MW-1, the weathered basalt rock was first encountered at a depth of 95 feet bgs. Drilling continued into the weathered basalt to 107 feet bgs where the rock became too dense to auger drill through. Based upon the assumption that the base of the perched aquifer coincided with the base of the saprolites, the borehole was grouted closed to a depth of 92 feet for well construction.

MW-2 was drilled to a depth of 79 feet bgs which was 11 feet into the weathered basalt. Due to the presence of an organic odor detected in a sample collected at 73-75 feet bgs in MW-2, the decision was made to install the monitoring well within the top portion of the weathered basalt. A portion of MW-2 well screen sand pack extends above the weathered basalt into the overlying saprolites.

Auger drilling in perched zone monitoring well MW-3 extended to a total depth of 85 feet bgs which was approximately 10 feet into the weathered basalt rock. A monitoring well was partially installed at this depth including the sand pack and a bentonite seal above the sand pack. After placing the bentonite seal above the sand pack, the water level within the well continued to drop until the well was nearly dry. Sealing off the well screen from the overlying saprolites resulted in the well no longer being in contact with the perched groundwater system. This provided evidence to support the assumption that the base of the perched groundwater system coincided with the top of the weathered basalt rock. In order to install a monitoring well at this location, the

partially installed well was drilled out to a depth of 85 feet. The bottom of the borehole was then filled with bentonite to a depth of 74 feet at which point MW-3 was installed.

#### 2.4.1.4 Perched Zone Monitoring Well Installation

Perched zone monitoring well installation was performed through the center of the auger flights using 2-inch inside diameter (ID) Schedule 40 PVC prepacked screen with 0.01-inch slots. The prepacked screen consisted of two five-foot lengths of 2-inch ID screen encased in 3-inch ID screen with the screen annulus filled with silica sand. The remainder of the well casing was 2-inch PVC with flush threaded, o-ring sealed joints. A filter pack consisting of Monterey #3 sand was placed around the well screen to a depth of approximately three feet above the top of the screen. A bentonite seal was placed above the sand pack. The remainder of the annular space was sealed to within three feet of ground surface using a Portland cement bentonite grout with 5% bentonite. The top three feet was filled with Quickcrete concrete during installation of the wells' surface monument.

All perched zone monitoring wells were completed with 8-inch diameter protective steel well monuments having lockable lids. Three concrete filled 3-inch diameter steel posts ("bumper posts") were placed in a triangular array around each protective monument to provide additional protection. A domed concrete pad was constructed around the base of the monument to divert water runoff away from the well. The protective monument and bumper posts were painted yellow. A weep hole was drilled at the base of the monument and the monument's annulus was filled with drainage sand. The wells were capped using an expansion cap. Monitoring well construction diagrams are included in Appendix B.

Perched zone monitoring wells were developed by surging with a surge block and bailing. Water quality parameters (pH, temperature, conductivity, and turbidity) were measured during purging. Well MW-2 was the only well of the three that yielded a sufficient volume of water to permit continuous bailing until a total of four well volumes were removed and field parameters stabilized. Wells MW-1 and MW-3 were bailed dry and allowed to recharge four times. Based upon rate of recharge, well MW-3 had the lowest specific yield of the three wells. Immediately following well development, a groundwater sample was collected from each well using a disposable Teflon bailor. The sample was analyzed for VOCs, EDB and DBCP. This final sample was used to supplement the hydropunch samples collected during drilling thus providing a vertical profile of the perched water system at the three monitoring well locations. Table 2-2 provides a summary of samples collected during monitoring well drilling and installation.

#### 2.4.1.5 Installation of Additional Perched Zone Monitoring Wells

Upon completion of the first phase of field sampling activities, the data collected was evaluated to optimize the second phase of field sampling activities. The data evaluation and second phase sampling recommendations were presented to the EPA in Technical Memorandum 97-4 (Golder 1997b). These recommendations were discussed with the

EPA and the following scope of work pertaining to the perched groundwater investigation was agreed upon:

- A second, shallower monitoring well was not required to be installed next to perched zone monitoring wells MW-1 and MW-2. The FSP describes the installation of nested monitoring wells screened within the perched groundwater system at the depth where the highest COPCs were detected during Hydropunch sampling. The primary reason for eliminating this task is that Hydropunch sampling results indicated that MW-1 and MW-2 are currently screened at depths representative of where the highest COPC concentrations were detected. In addition, no boundary layers were observed within the saprolites to prevent vertical migration, and the vertical extent of the saturated zone was observed to be much shallower than originally estimated.
- A second monitoring well would be installed next to monitoring well MW-3. The second well (MW-3S) would be screened from 30 to 40 feet which is the depth interval where the highest concentration of DBCP was detected during Hydropunch sampling in MW-3.
- In order to determine the lateral migration of COPCs in the perched groundwater system, two additional perched zone monitoring wells (MW-4 and MW-5) and potentially a third (MW-6) would be installed approximately 150 feet downgradient of MW-3.

Implementation of this scope of work is described below.

MW-3S

The nested shallow monitoring well MW-3S ("S" is for shallow) was installed approximately 8 feet from MW-3 using auger drilling and well installation methods described in Section 2.4.1.4. No samples were collected during drilling. Table 2-3 provides the well installation details.

MW-4 and MW-5

Locations originally proposed for perched zone monitoring wells MW-4 and MW-5 were selected based upon the most probable lateral migration pathways downgradient of the Former Fumigant Storage and Mixing Areas. Perched groundwater level elevations measured in the piezometers indicated that the lateral gradient of the perched aquifer was in a northeast or easterly direction. In addition, the perched groundwater analytical results obtained from the first phase of sampling indicated elevated concentrations of COPCs in well MW-3 (the nature and extent of COPCs is discussed in Section 4). As such, MW-4 and MW-5 were located to determine how far COPCs detected in the perched groundwater at MW-3 had migrated. Figure 2-16 depicts the locations of MW-4 and MW-5.

MW-4 was drilled using auger drilling as described above. Soil samples were collected during drilling for lithologic description. After drilling to a depth of 59 feet, the auger flights were lifted up approximately five feet and the hole remained undisturbed overnight. No water collected in the open hole. The borehole was then drilled to a total depth of 80 feet bgs which was approximately 10 feet into the top of the weathered basalt rock. All auger flights were removed from the hole. The open hole was monitored after 24 hours. No water had collected in the open borehole, and the hole remained open to 78 feet bgs. No visual indications of intercepting the perched aquifer were observed in the samples collected during drilling. The perched aquifer does not appear to be present at this location; as such, a monitoring well was not constructed at the MW-4 location. The borehole was grouted closed with cement/benonite grout. Auger drilling was attempted at eight different locations in the proposed MW-5 area. Large basalt boulders were encountered throughout this area which the auger drill was not capable of penetrating. In order to drill through the boulders, a Tubex drilling system was used. The Tubex system utilized a 10-inch diameter air activated hammer button bit. MW-5 was located 110 feet east of MW-3. The MW-5 borehole was drilled to the top of the weathered basalt which started at approximately 71 feet bgs. No samples were collected for analyses during drilling. The MW-5 well was installed in the open borehole using the well construction materials and methods described above in Section 2.4.1.4.

Following well installation, MW-5 was developed by bailing until a total of three well volumes had been purged from the well casing and sandpack and field parameters had stabilized. Following purging a groundwater sample was collected for analysis of VOCs (Method 8260), and EDB and DBCP (Method 504).

MW-6

Based upon a positive detection of EDB and DBCP in perched zone monitoring well MW-5, the decision was made and approved by EPA to install an additional monitoring well further downgradient of MW-5. Well MW-6 was installed using the Tubex drilling system at a location 130 feet from MW-5 in a roughly straight line extended from MW-3 (see Figure 2-16). MW-6 was drilled to a total depth of 87 feet bgs. The hole sloughed in to 78 feet bgs prior to monitoring well construction. Perched zone monitoring well MW-6 was screened from 68 to 78 feet bgs using the well construction materials described above. The sand pack was extended to 50 feet bgs, and the annulus was sealed above the sand pack using bentonite hole plug. The surface monument and bumper posts were completed as described in Section 2.4.1.4. Table 2-3 provides monitoring well construction details. Borehole logs and well construction diagrams are included in Appendix B.

MW-6 was developed by bailing approximately four well volumes from the well casing and sand pack. Bailing continued until field parameters had stabilized. Following well development MW-6 was sampled as part of the perched groundwater monitoring well sampling program discussed in the following section.

### 2.4.1.6 Perched Groundwater Monitoring Well Sampling Program

In addition to the perched groundwater sampling conducted during monitoring well drilling and well installation, a quarterly groundwater sampling program has been established for the six perched groundwater monitoring wells (MW-1, MW-2, MW-3, MW-3S, MW-5 and MW-6).

The first round of perched groundwater sampling was completed in September 1997, and included all perched zone monitoring wells except MW-6 which had not yet been drilled. MW-6 was first sampled on October 24, 1997. A second complete round of samples were collected from all wells but MW-6 on October 22-23, 1997. The second sampling of MW-6 was completed on November 20, 1997. EPA's consultant, ICF Technology, Inc., was present during the second sampling of MW-6 and collected a split sample. A third sampling round was completed in January 1998. As such, five complete sample rounds had been completed from all six perched zone monitoring wells by the end of July 1998. At the request of EPA, existing perched extraction Well No. 9 has been added to the perched groundwater monitoring program and was sampled in Dec-97, Jan-98, May-98 and July-98. During the July-98 sampling, insufficient water was present in MW-3S to permit sample collection. The absence of water in well MW-3S was the result of lowering of the perched groundwater caused by recent drought conditions.

Groundwater samples are collected from perched zone monitoring wells following Golder Technical Procedure TP-1.2-20 "Collection of Groundwater Quality Samples." Perched zone monitoring wells are purged prior to sampling using dedicated stainless steel or teflon bailors. Field parameters (pH, conductivity, turbidity, and temperature) are monitored during purging. Purging continues until three well volumes have been removed and field parameters have stabilized. Monitoring wells which purge dry prior to removing three well volumes are allowed to recharge for approximately one hour prior to sample collection. Samples are collected using dedicated stainless steel or teflon bailors. Existing perched extraction well no. 9 is purged using the pump system previously installed in the well. The samples are collected directly from the pump discharge hose.

Perched aquifer groundwater samples collected during the first four sampling rounds were analyzed for the full COPC list of constituents which includes: VOCs via EPA Method 8260, lindane, toxaphene and heptachlor by EPA Method 8081, EDB/DBCP by EPA Method 504.1, TPH-Diesel using EPA Method 8015M, PAHs by EPA Method 8310, bromacil and diuron (Method 632), ametryn (Method 619), and fenamiphos (Method 8141). After receiving approval from EPA, TPH-diesel, PAHs, ametryn and fenamiphos were eliminated from the list of required groundwater analyses during the July-98 sampling round. The justification for the elimination of these parameters was provided to EPA in Technical Memorandum 97-6 rev. 1 (Golder 1997f). The eliminated analytes were either not detected or were detected at concentrations below regulatory limits.

### 2.4.1.7 Hydraulic Testing of Perched Water Bearing Zone

The objectives of the testing program were to derive hydraulic parameters that may be used to both help estimate the lateral and vertical extent of contamination in the groundwater system, and to evaluate and select remedial alternatives, if deemed to be necessary. Both the shallow perched water in the saprolite and the basal aquifer in the basalt were investigated (the basal aquifer testing is described below in Section 2.4.2.3.5). Slug tests were performed in the perched water to determine local hydraulic properties. Slug tests were performed in 2 inch diameter monitoring wells MW-1, MW-2, MW-3, MW-3S, MW-5, MW-6 and in 1 inch diameter piezometers P-3, P-4 and P-6. It was not possible to perform tests in P-7 and P-8 as silt had filled the bottom of the borehole to near the water table. Full details of the slug testing procedure, analysis, and results are included in Appendix E.

#### 2.4.1.7.1 Software

Golder's in-house program FLOWDIM, version 3.14, was used to interpret slug test data with the deconvolution method (Chakrabarty and Enachescu, 1997). The deconvolution method and conversion of slug test data to equivalent constant rate allows for significantly improved recognition of the flow model resulting in improved reliability of derived parameters. This technique incorporates both the pressure change and the derivative of pressure change to reduce ambiguity in the analyses.

#### 2.4.1.7.2 Equipment

The response of the aquifer to induced disturbances and barometric changes was measured with Geokon Vibrating Wire Transducers, Model 4500L. The transducer has a 0 - 10 psi range with a 0.05 psi accuracy and 0.0025 psi resolution. The gauges measure changes in both water levels and atmospheric pressure. Atmospheric pressure changes were monitored on site manually with a Weens and Plath Barometer. In regards to test data , the resolution is the most important specification as hydraulic parameters are derived from absolute pressure changes. For the 10 psi gauge, pressure changes of 0.0025 psi (0.07 in. of hydraulic head) or greater can be recognized above gauge noise.

#### 2.4.1.7.3 Test Design

The slug test procedure is detailed below:

1. Measure static water level with an electric tape and place transducers in well below the water table;
2. Monitor static conditions prior to start of test to evaluate barometric effects or significant interference effects;
3. Perform at least 1 withdrawal and 1 injection test utilizing either 1 gallon of deionized water injected at the surface or a solid PVC rod;
4. Repeat test if results are anomalous; and
5. Continue test until at least 90 % recovery is obtained.

Due to restrictions from the small diameter of the piezometers, the slug tests were limited to the injection type and water level changes were monitored with a stop watch and electric tape. All tests in the monitoring wells were performed with pressure transducers with the exception of MW-6. This borehole was drilled after the transducers were returned to the manufacturer and therefore, an injection test was carried out with an electric tape and stop watch.

No significant barometric or interference effects were detected with the exception of tests performed in MW-5. These tests show anomalous responses in mid to late time data and recovery to non-static conditions. The test was repeated several times with the same atypical response. Hence, the analysis approach was to analyze the early time data, prior to the non-formation responses, to derive the appropriate hydraulic parameters.

2.4.1.7.4 Slug Test Analyses

The slug analyses procedure was as follows:

1. Identification of the flow model by evaluation of the derivative data on the log-log diagnostic plot;
2. Match the data to the appropriate type curves;
3. Examine the match on Ramey A, B, and C with each plot emphasizing different parts of the data set; and
4. Iterate between plots until the quality of fit is optimized.

The Ramey A analyses, equivalent to the Cooper technique, was typically selected to show the match between the data and type curves. The data was matched with two models: homogenous and composite. The composite model is recognized as two stabilization's or leveling off of the derivative data on the log-log deconvolution plot. Each stabilization represents a radial cylindrical region about the well with different transmissivities. The outer zone transmissivity is considered to be more representative of the formation response as the inner zone parameters may be influenced by the disturbed zone adjacent to the well.

The derived storativity is less well constrained compared to transmissivity due to its correlation to skin. In most cases the skin was assumed to be zero due to the lack of "clean" early time data to select the appropriate type curve. Hence, if the actual skin is 2, the storativity will be underestimated by approximately 2 orders of magnitude.

Results of the slug testing in perched aquifer monitoring wells and piezometers are shown in Appendix E and discussed in Section 3.5.2.2.

### 2.4.2 Basal Aquifer Studies

#### 2.4.2.1 Rationale and Approach

The Work Plan (ICF 1997) and Field Sampling Plan (Golder 1996a) outlined a phased approach for the basal aquifer investigations. The first step of this phased approach was to conduct a series of activities, termed "vertical profiling" to evaluate the vertical distribution of chemicals within the Kunia Well, and the possibility of chemical migration through the well's annulus from the perched groundwater aquifer to the basal aquifer. The primary purpose of the vertical profiling was to determine if the screened interval of the Kunia Well is suitable for monitoring and if there is evidence that the well itself serves as a conduit for vertical migration from the perched aquifer.

The results of the vertical profiling investigative activities were to be used, during implementation of the RI, to assess subsequent steps in the basal aquifer investigation. If evidence was obtained that the Kunia Well is acting as a conduit and/or is unsuitable for monitoring, then retrofitting or upgrading the well to a useful condition were to be considered as options. Abandonment of the well and installation of a replacement well or retrofitting of the well were to be considered only if EPA determined the well to be a current conduit. Although EPA will make a final determination on the future of the Kunia Well at a later date, the Kunia Well was determined to be suitable for monitoring purposes. In this case, the next step in the basal aquifer investigation was to install a downgradient basal monitoring well and proceed with the performance of a two well pumping test to measure site-specific hydraulic properties and obtain chemical data. The data from the vertical profiling were also to be used to assist in the design of the downgradient basal well (i.e., the location of the well and position of the well screen).

In order to meet these aims, the approach presented in the Work Plan included the following general items for vertical profiling:

- Point sampling from discrete depths within the Kunia Well water column, to assess the vertical distribution of chemicals within the well and aquifer;
- Temperature/fluid resistivity logging to identify possible preferential flow zones into or out of the well, and natural gamma logging for stratigraphic interpretation; and
- The performance of a video log of the interior of the well to assess the condition of the well casing/screen and to visually check for possible inflow of perched groundwater into the well.

The results of the vertical profiling activity, originally presented to EPA in TM 97-2 (Golder 1997c), indicated that the chemical concentrations did not vary significantly over the 150 ft screened interval of the Kunia Well. These results indicated that the Kunia Well does not serve as a conduit for chemical migration to the basal aquifer, and the well was suitable for use as a monitoring well and for aquifer testing purposes. As such, it was proposed that a replacement for the Kunia Well not be installed, and the RI proceed with installation of a downgradient basal well and performance of the two-well pumping test. The rationale and justification for the pumping test, as well as the design

of the downgradient well were presented in TM 97-3 (Golder 1997d). EPA provided their approval, of the installation of the new downgradient monitoring well and to conduct the two-well pumping test, during two conference calls on July 23 and August 1, 1997. EPA stated that the data were not conclusive to determine whether the Kunia Well was acting as a conduit.

Following the completion of the vertical profiling, the basal aquifer investigation proceeded with the following field investigative items:

- Drilling and installation of a 993.5-ft deep, 8-inch diameter downgradient Basal Well, located some 156 ft south of the Kunia Well;
- Performance of a two-well pumping test using the Kunia Well as the pumping well, and the new downgradient Basal Well as the observation well, in order to assess site specific hydraulic properties and obtain chemical data; and
- A program of periodic basal well sampling, involving the Kunia Well, new downgradient Basal Well, and selected regional basal aquifer wells.

Implementation of these activities is detailed below.

#### 2.4.2.2 Kunia Well Vertical Profiling

As indicated above, the Kunia Well vertical profiling included the following activities:

- vertical distribution sampling of the water column over the 150 ft screened interval;
- geophysical logging of the well; and
- performance of a video log.

These are discussed below.

##### 2.4.2.2.1 Vertical Distribution Sampling

###### 2.4.2.2.1.1 Purging

Prior to performance of the vertical profile sampling, the Kunia Well was purged using the well's downhole pump. The purging took place on March 12, 1997. A total of approximately 7,500 gallons of water was pumped from the well. This volume of water corresponds to approximately 4 well volumes assuming a depth to water of approximately 825 ft, a well diameter of 17.5 inches, and total well depth of 976 ft. Purging and groundwater sample acquisition were conducted in accordance with Golder Technical Procedure TP 1.2-20 "Collection of Groundwater Quality Samples."

The water discharged from the Kunia well was collected in the existing 9,000 gallon storage tank located within the fenced area of the Former Fumigant Storage and Mixing Areas. The location of the Kunia Well and the existing storage tank are shown in Figure 2-1. In accordance with Golder's letters to EPA of April 18 and 25, 1997, storage of the

purgewater in the existing above ground steel storage tank was conducted in accordance with 40 CFR 262.34. EPA provided approval for the use of the existing storage tank in a letter dated June 20, 1997.

Because the well's pump will produce approximately 300 gallons per minute (gpm) and the capacity of the storage tank is only about 9000 gallons, pumping at the full rate would fill the tank in approximately 25 minutes, leaving little time for field measurements and sampling. Therefore, the main flow control valve at the wellhead was partially closed in order to limit the flow rate to as small a value as possible. Pumping occurred over a period of about 75 minutes at an approximate flow rate of 100 gpm. The flow rate was estimated via a totalizing inline flow meter installed at the well head. During purging, the meter became clogged with debris and stopped functioning. Because of the this, the final total volume which was pumped was determined by measuring the depth of water in the storage tank and the tank dimensions. A table summarizing the meter readings during purging, and indicator parameter measurements is shown in Table 2-4.

Indicator parameters pH, electrical conductivity, and turbidity were monitored throughout purging. Final values for these parameters were 6.72, .23 mS/cm, and 15 NTUs, respectively.

A water sample was collected near the beginning of purging and the end of purging for chemical analysis. The initial sample was collected after approximately 1,500 gallons water was pumped. The final sample was collected after approximately 7,500 gallons water was pumped. The samples were collected from a sampling port (gate valve) located at the wellhead. Personnel from the HDOH also collected a sample at the conclusion of pumping.

2.4.2.2.1.2 Vertical Distribution Sampling

Following purging, the pump and riser pump were pulled from the well. This took place on March 13 and 14, 1997 by Roscoe Moss Hawaii, Inc. (RMH) in preparation for the Niskin sampling. Because several check valves are installed in the pump and riser pipe string, the riser pipe was completely full of water during pump removal. As the pipe strings were removed from the well, this water (approximately 800 gals) was pumped into the existing storage tank for containment purposes using a small electric submersible pump. Purge water stored in the storage tank was sampled March 26, 1997.

The riser pipe pulled from the well consists of 40 sections of 5-inch diameter steel pipe. The pipe lengths vary from about 20 to 24 ft in length with an average length of about 22 ft. The total length of riser pipe is therefore approximately 880 ft. The intake of the pump is located approximately 8 ft below the top of the pump. The first section of riser pipe attaches to the wellhead approximately 2 ft below ground surface. The pump intake is therefore believed to have been set at approximately 890 ft below ground surface in the well. The joints on the riser pipe were corroded making it impractical to place back into the well. To provide consistent operation the pump was serviced by

RMH and new riser pipe was purchased. Prior to the pumping test (discussed in Section 2.2.3.5), the pump and new riser pipe were returned to the well.

On March 15, 1997 the initial attempt was made to perform the Niskin sampling. Prior to sampling, the water level was measured in the well at 824.3 ft below ground surface (elevation of 22.95 ft amsl) using a 1000 ft long Solinst water level indicator. Ground surface (top of concrete pad) at the Kunia Well is approximately 847.25 ft above mean seal level (AMSL). The depth to groundwater in the monitoring well was measured in accordance with Golder Associates Technical Procedure TP 1.4-6 "Technical Procedure for Water Level Measurement."

The NISKIN sampling device consists of a Teflon lined 1.2L PVC pipe with spring loaded end-caps (with o-ring seals). The sampler is lowered into the well on a cable with the end caps locked in the open position. Once the sampler reaches the intended sampling depth, a brass messenger device affixed to the cable is dropped from ground surface. When the messenger strikes a plunger on the sampler, the end caps are released causing the sampler to close. The sampler is then retrieved. The first depth at which sampling was attempted was approximately 827 ft, or 3.5 ft below the water table surface. Unfortunately, the momentum of the weighted messenger during its free-fall of 824 ft was sufficient to cause damage to the sampling device upon impact which rendered it inoperable. At that point, it was decided by Golder that the Niskin sampler was impractical for this type of application, and sampling was conducted using a TIMCO dual-valved, closed-top, stainless steel point source bailer. This bailer allowed the collection of discrete point samples at selected depths in the water column. Golder informed EPA of the possibility of such a change in sampling procedure in a facsimile of March 14, 1997.

The point-source bailer is essentially the same as other bailers, except that it has a check valve at the top in addition to the valve at the bottom of the bailer. While the bailer is lowered, the check valves remain open allowing water to flow freely into the bailer. Once the bailer is raised upwards, the check valves seat, thereby sealing in a sample from a discrete interval.

Sampling for the uppermost sample (at 827 ft) was completed on March 15. The remaining samples were collected the next day. A total of 15 samples were collected plus one equipment blank, one trip blank, and one duplicate sample. The samples were collected at ten ft intervals with the deepest sample at 967 ft. Sampling was not possible below that depth due to the presence of accumulated sediment at the bottom of the well. The bottom of the well was measured with a weighted cable at a depth of approximately 971.5 ft bgs. The total depth of the well is reported to be 976 ft bgs (ICF 1995; HDOH 1996). Presumably, sediment and normal piping debris has accumulated over the years at the bottom of the well.

The groundwater samples collected during well purging were analyzed for EDB/DBCP (EPA Method 504). The sample of the purge water tank was submitted for EDB/DBCP (EPA 504) and volatile organics analysis (EPA Method 8260). The uppermost point source bailer sample was submitted to the laboratory for the complete list of chemicals of

potential concern (COPCs). All subsequent bailer samples were submitted only for EDB/DBCP (EPA Method 504) and volatile organics analyses (EPA Method 8260). Table 2-5 lists the samples collected with the point source bailer and analyses conducted.

All groundwater samples were collected in clean bottles of appropriate volume and type, as specified in the QAPP. The bottles were filled completely to eliminate any air bubbles in the sampling vial. After filling, the bottles were immediately sealed, labeled and placed in a cooler with ice. Samples were stored in an onsite sample refrigerator until transported to the analytical facility under formal chain of custody documentation. Sample coolers were sealed with custody seals.

The NISKIN sampler and discrete point source bailer were decontaminated prior to use and between uses by a process involving an Alconox water wash and tap water rinse, followed by a final distilled water rinse. The stainless steel cable used to lower the sampling devices consisted of brand new, 1/4-in stainless steel cable. The cable was steam cleaned prior to use.

The results of the laboratory analyses on the purge water samples, tank sample and vertical profiling samples are summarized in Appendix A and presented in Chapter 4.

2.4.2.2.2 Downhole Geophysical Testing

Temperature/fluid resistivity logging and natural gamma logging were conducted in the Kunia Well on March 19 and March 20, 1997, respectively, using a Mount Sopris MGX logging system. The borehole had been undisturbed since March 17 when the initial video log was conducted. The results of the logging are presented in Section 3.5.2.2.2. All downhole geophysical logging was conducted according to Golder Associates Technical Procedure TP-1.1-18 "Downhole Geophysical Logging."

Temperature/fluid resistivity logging was conducted from the top of the water table surface down to the bottom of the hole, at a speed of approximately 6 to 8 ft/min. Prior to logging, the probe was calibrated at the surface using 2 water solutions of known temperature and conductivity.

The natural gamma logging was conducted from the bottom of the borehole to the top at a speed of approximately 6 to 8 ft/min.

2.4.2.2.3 Video Log

The Kunia Well was video logged on three separate occasions by Golder and RMH. The first log was conducted March 17, 1997. The log was conducted to a total depth of about 850 ft, or approximately 25 ft below the water table surface. Due to a malfunctioning camera and light, a second video log was conducted on April 8 after the camera was returned to the manufacturer for repairs. This video, which was of good quality, was conducted to the water table surface only due to the presence of debris observed just below the water table. In order to attempt to view the portion of the well below the

water table, a third video log was conducted on April 24, 1997. This log, which was of good quality, was performed to a depth of about 850 ft bgs. All video logs were recorded in color onto VHS format tapes. Copies of the videos are retained by Golder, RMH and DMFP and are available for review upon request. Copies of the video logs were also provided to EPA in July 1997. Results of the video logging are presented in Section 3.5.2.2.2.

### 2.4.2.3 Basal Aquifer Drilling and Well Installation

#### 2.4.2.3.1 Basal Well Design

Results from the vertical profiling indicated organic chemicals are present at relatively constant levels within the upper 150 ft of the basal aquifer at the Kunia Well (discussed further in Chapter 4). Therefore, it was proposed in TM 97-2 (Golder 1997c) that the downgradient basal well be screened over the same 150 ft portion of the aquifer. EPA provided verbal approval of the proposed screened interval in a phone conversation of May 29, 1997, but requested additional information regarding the location proposed for the well in the Work Plan. Information presented in TM 97-3 (Golder 1997d) indicated that the location proposed in the Work Plan, approximately 150 ft south of the Kunia Well, was appropriate based on the anticipated direction of groundwater flow and the estimated drawdown at the well anticipated during a two-well pumping test using the Kunia Well as the pumping well. EPA provided their approval of the well location during conference calls of July 23 and August 1, 1997.

The Work Plan (ICF 1997) indicated that the downgradient basal well was to be constructed as a 6-in diameter monitoring well. DMFP's environmental consultant, Mink and Yuen, Inc., recommended installing a larger diameter well, consisting of 8-inch diameter well casing, to facilitate future options for use of the well at the site. Installation of this larger well will not in any way detract from or affect the usefulness of the downgradient well in this remedial investigation, the representativeness of the groundwater samples collected from the well, or the quality of the data.

#### 2.4.2.3.2 Basal Well Drilling

The downgradient basal well (State Well #2703-02) ("Basal Well") was drilled to a total depth of 993.5 feet below ground surface (ft bgs) between September 11 and October 6, 1997 by RMH. The well installation was completed on October 16, 1997. The State of Hawaii approved a Well Construction Permit prior to the start of drilling activities. Pertinent details for the borehole and well installation are summarized in Tables 2-6 to 2-8. The location of the downgradient basal well is shown in Figure 2-16. The boring log and well construction diagram is presented in Figure 3-20.

The location of the Basal Well was placed approximately 156 feet south of the Kunia Well. This location was selected to provide useful data necessary to meet the RI objectives. The proximity of the Basal Well to the Kunia Well was critical in the determination of hydraulic properties during the two-well pump test due to the anticipated small drawdown. In addition, the Basal Well was located to ensure

intercepting a plume if present, and to provide data that could be used for fate and transport modeling of potential environmental risks posed by site COPCs.

Prior to drilling, soil containing petroleum hydrocarbons in the vicinity of the Basal Well was excavated. The excavated soils were tested for petroleum constituents and metals followed by treatment using thermal desorption by Pacific Thermal Services, Inc., an HDOH approved treatment facility. Grab samples were collected in the excavation cavity to confirm meeting HDOH clean-up criteria. DMFP provided HDOH and EPA excavation sampling results in the form of a Closure Report. Following excavation, a 20 inch O.D. conductor casing was then installed in the pre-existing excavation to a depth of 10.2 ft bgs. Powdered bentonite was placed around the outside of the casing to act as a seal. The excavation was then backfilled around the conductor casing to a depth of approximately 4 to 5 ft bgs. Cement was then used to create a working pad for the drill rig to the surface.

Drilling was performed with a top drive air rotary rig using a 900 standard cubic feet per minute (SCFM) compressor. The circulation medium was "AMPLI-FLOW" foam. The foam was circulated down through the drill pipe, out through the drill bit, and then upward in the annular space between the hole and drill pipe to the surface, carrying the cuttings in suspension. At the surface the foam was washed to remove cuttings. The cuttings were logged by a Golder field hydrogeologist and archived, typically in 5-foot intervals. No lost circulation zones were encountered while drilling.

Drilling started at 10.2 ft bgs with a 17.5 inch tricone bit and continued to 202.8 ft bgs, some 12.8 ft below the top of the competent basalt. The drilling was interrupted to install 14 inch O.D. surface casing. The annular space between the casing and the borehole walls was sealed with neat cement containing 3-5% bentonite. The seal was placed with a tremie pipe.

The drilling resumed at 202.8 ft bgs with a 12.25 inch tricone bit and continued to the total depth of 993.5 ft bgs. Deviations surveys were performed with a TOTCO model 26-26A approximately every 30 ft. If the deviation measurements were greater then 30 minutes, the interval was "reamed" by running the drill bit up and down the interval until the deviation was corrected. In addition, Baker Hughes INTEQ performed a gyroscopic multi-shot survey to measure the deviation in three coordinates after installation of screen and casing. The results show a total deviation of 2.66 ft in the horizontal direction of S 41.70 E, well within state regulations. The survey also shows that water levels need to be subtracted by 0.01 ft to obtain the true vertical distance from the ground surface. The results of the Hughes deviation survey are shown in Appendix F.

After the total depth of the borehole was reached, the tools were removed to the surface and preparations were made for well casing and screen installation. First, a 13 inch diameter "cage" was constructed and lowered to the bottom of the hole on a wireline. As the cage reached the bottom of the hole, the open borehole diameter was confirmed to be at least 13 in. and sufficiently large to accommodate both the 8.625 inch O.D. casing and 1.5 inch tremie pipe. The larger hole in relation to the 12.25 inch bit size can be

attributed to reaming. Secondly, 60 ft of 8 inch casing was welded together and lowered to the bottom of the borehole on a wireline. This was done to confirm that there were no significant deviations in the borehole that would cause restrictions during well installation. No significant deviations were observed.

2.4.2.3.3 Basal Well Construction

The well screen consists of Roscoe Moss 8 $^5/_8$-inch OD Type 304 stainless steel "Ful-Flo" louvered screen with 0.25 inch wall thickness (ASTM A-409). The casing was Corten 8 $^5/_8$-inch OD steel blank casing with 0.312 inch wall thickness (ASTM A-606-75 Type 4). The louvered screen openings are 3/16 inch diameter and provide 29 in.$^2$ of open area per linear ft. A stainless steel louvered screen was chosen for its greater strength over the more commonly used continuous slot type. Figure 3-20 includes a well construction diagram of the Basal Well.

The 8-inch screen and casing were installed by welding approximately 20 ft sections with stainless steel welds. The top of the 150.5 ft length of screen with end cap was placed at 820.6 ft bgs, some 5.4 ft above the top of the water table. The seasonal fluctuations in the potentiometric surface are expected to be less then 5 feet; therefore the top of the screen will normally be above the water table.

Annular material was placed around the screen and casing to enhance specific capacity and seal off perched water bodies to prevent vertical migration along the borehole. Several measures were taken to ensure that the annular material was placed at the correct depth and to assure that material did not bridge resulting in air gaps: 1) the theoretical annular volume was calculated, 2) volume of material placed in the hole was accurately measured, 3) the depth to the top of the annular material was frequently taken with a sounding rod, and 4) a tremie pipe was used.

All material placed in the annulus below the water table was washed. Chemical analyses were provided to ensure the lack of significant amount of carbonate material, and sieve analysis was conducted by the supplier to ensure compatibility with the size of the screen openings. Basalt chips (3/8 inch) were placed in the open hole below the bottom of the screen. Washed gravel (3/8 inch) was used to fill the annular space adjacent to the screen to 841.9 ft. When the supply of washed gravel brought onsite was exhausted, locally supplied basalt chips were then used to fill the annular space to 810.2 ft, some 10.4 ft above the top of the screen. A 13.5 ft seal of fine sand and bentonite chips was placed above the basalt to prevent the downward vertical migration of the overlying grout seal.

The mixture for the grout seal above the sand pack consisted of 7 gallons of water per 94 pound bag of Portland Type I-II cement with 3 to 5 % powdered bentonite. This mixture was used to fill the annular space to 600.1 ft bgs. Above this point, sand was added at equal parts to cement to prevent loss of grout into the formation. In general, the annular material used was greater then a factor of 2 compared to the theoretical annular space volume.

The Basal Well surface completion consisted of finishing off the 8-inch well casing with a blind flange to which the pump and 1-1/2 inch sounding tube could be secured. A 24-inch steel protective cover with locking lid was cemented in place around the well surface. Protective bollards were installed around the well concrete landing.

2.4.2.3.4 Basal Well Development and Pump Installation

Well development is required to grade the sand pack to optimize production and remove foam that entered the aquifer while drilling. The well was developed with air on October 17, 1997 for 4 hours at a discharge rate of 20 gpm. During this time, the appearance of the water changed from murky to clear. On October 20, 1997 a Myers 7.5 HP electrical sampling pump was installed. The pump was used to further develop the well by pumping at 20 gpm for over 50 hours. The pump intake is located at 885.0 ft bgs and contains a 2 inch I.D. discharge pipe (Figure 3-20). All development water was treated with the existing carbon adsorption unit.

2.4.2.3.5 Basal Aquifer Pumping Test

A constant rate withdrawal and recovery test was conducted in the basal aquifer to derive site-specific values for basal aquifer hydraulic properties and qualitative information for the geometry of the flow system. The Kunia Well served as the pumping well with the Basal Well as the observation well at an approximate distance of 156 feet. Pumping was conducted using the original pump removed from the Kunia Well in March, 1997. The pump had been serviced and rebuilt by RMH and re-installed in the Kunia Well. New 5 inch carbon steel riser pipe was installed with the pump. Complete details of the test and data analysis are shown in Appendix E.

The response of the aquifer to induced disturbances and barometric changes was measured with Geokon Vibrating Wire Transducers, Model 4500L. A 0-50 psi instrument was used to monitor background barometric changes and water level changes in the pumping well. A 0-10 psi instrument was used in the observation well. Atmospheric pressure changes were monitored on site manually with a Weens and Plath Barometer. The static conditions in the Kunia Well and atmosphere were monitored for some 24 days with a pressure transducer starting on September 17, 1997.

The pumping rate was approximately 325 gpm. Pumping occurred at this rate for a period of approximately 45 hours. Samples were collected from a sampling port located at the well head during the pump test. Samples were collected at the start of pumping, and at 1 hour, 2 hours, 3 hours, and 24 hours into the pump test. These samples were analyzed for VOCs and EDB and DBCP. A final sample was collected at the very end of the pump test, 46 hours after the start of pumping. The final sample was analyzed for the full COPC list of analytes. Additional chemical data was obtained during a second pumping test which occurred during the period of November 14-16, 1997. Samples were collected at 0.5 hours, 4 hours, 24 hours, and 48 hours into the pump test. All samples were analyzed for EDB and DBCP. Water discharged from the Kunia Well was treated with the existing carbon adsorption unit.

2.4.2.4 Basal Aquifer Sampling

The Work Plan (ICF 1997) and FSP (Golder 1996a) requires that the Kunia Well, the Basal Well, and three regional wells be monitored to provide basal groundwater quality data. The regional wells monitored are the Navy Well, the Hawaii Country Club Well, and a well at the U.S. Air Force's Waikakalaua Fuel Storage Annex (FSA). The Waikakalaua FSA Well was subsequently replaced with the Honouliuli Well (2303-03). The Kunia Well is located within the Spill Area and approximately 150 to 300 feet south-southeast of the Former Fumigant Mixing and Storage Areas in the Kunia Village Area. The Basal Well (State well # 2703-02) is located approximately 156 feet south of the Kunia Well. In the general area, basal groundwater flows towards the south. The Kunia Village Area wells were sampled monthly for three months and then quarterly for three quarters. The regional wells were monitored quarterly. The locations of these wells are shown in Figures 2-17 and 2-18.

This sampling program was conducted over the course of one year. Basal aquifer sample collection dates are summarized in Table 2-9.

Sampling procedures conducted at the various wells are summarized below:

2.4.2.4.1 Kunia Village Area Wells

The Kunia Village Area basal wells consist of the Kunia Well and the new downgradient Basal Well (State well #2703-02). These two wells are to be sampled monthly for three months and then quarterly for three quarters. As discussed previously in this section, the Kunia Well was also sampled both during vertical profiling and during the pumping test. The sample collected from the Kunia Well at the end of the pump test, on October 20, 1997, served as the first monthly sample. The Basal Well was first sampled on October 23, 1997. The second monthly samples for the Kunia Well and Basal Well were collected on November 24, 1997 and November 20, 1997, respectively. ICF Technology, Inc., EPA's consultant, collected duplicate samples from the two wells during the November sampling. Additional groundwater samples were collected from the Kunia Well during a two day pump test conducted on November 14 - 16, 1997. Samples were collected for EDB and DBCP analysis at the time intervals of 30 minutes, 4 hours, 24 hours and 48 hours after start of well pumping. The third monthly sampling was conducted in December 1997. Both Kunia Village Area basal wells were sampled again in January 1998, May 1998, and July 1998.

Samples are collected from the wells by first purging a sufficient volume of water from the well casing and filter pack to ensure that the water collected is representative of the surrounding aquifer. Standard practice is to calculate the volume of water contained within the well casing and filter pack and to purge three times that volume prior to sampling. During sampling of the Kunia Well and Basal Well at least five well volumes are purged prior to sample collection. The purged water is treated through the on-site carbon adsorption unit and used for irrigation of non-crop areas.

Following well purging, sample containers are filled from the sampling port located at the well head. Sample containers are labeled and maintained in a sample refrigerator until transported to the laboratory under chain-of-custody procedures. Groundwater samples from the first three monthly sampling rounds and the January 1998 and May 1998 sampling were analyzed for the full COPC list of analytes. After receiving approval from EPA, TPH-diesel, PAHs, ametryn and fenamiphos were eliminated from the list of required groundwater analyses during the July-98 sampling round. The justification for the elimination of these parameters was provided to EPA in Technical Memorandum 97-6 rev. 1 (Golder 1997f). The eliminated analytes were either not detected or were detected at concentrations below regulatory limits.

The results of basal well sampling are presented in Chapter 4. Results of additional sampling will be forwarded to EPA in subsequent RI Addenda, as analysis and data validation are completed.

2.4.2.4.2 Regional Basal Wells

Three regional basal groundwater supply or monitoring wells were proposed in the Work Plan to be included in the groundwater monitoring program: the "Navy Well," the Hawaii Country Club Well, and a well in the Waikakalaua FSA area (Well ST12MW05). Figures 2-17 and 2-18 depict the off-site well locations. The "Navy Well" provides information on the water quality up-gradient of the site. This well is in an approximate up-gradient monitoring location and the well is located within an area of similar land use (pineapple cultivation). However, the well is not located in the same basal aquifer water bearing zone, but intercepts water emanating from the Schofield Barracks area and that ultimately flows through the basal aquifer underlying the Kunia Well Area. The Hawaii Country Club Well, the closest basal well located to the south of the Kunia Well, provides information on water quality that is potentially down-gradient of the site. Basal monitoring well ST12MW05 located on the southern edge of the Waikakalaua FSA and east of the Kunia Village Area was identified in the work plan as possibly providing background data on the concentration of COPCs in the Pearl Harbor Aquifer migrating towards the Kunia Well. Figure 2-18 depicts ST12MW05 in the Waikakalaua FSA area.

The Waikakalaua FSA well ST12MW05 was sampled in Feb-98. The Waikakalaua FSA well ST12MW05 was determined to be neither up- or down-gradient of the Kunia Village Area and as such provided little or no benefit to the RI program and was therefore not sampled during the subsequent monitoring rounds. Data collected during the RI indicated that sampling from the Honouliuli II series of wells would provide additional water quality data from a portion of the Waianae aquifer that is potentially downgradient of the Kunia Village Area. As such, the Honouliuli II Well #2303-03 was added to the regional basal groundwater sampling program and was sampled in May-98 and Jul-98. Figure 3-14 depicts the location of the Honouliuli Well #2303-03. The objectives, rationale and justification for the addition of the Honouliuli II well and the elimination of the Waikakalaua FSA well were presented to EPA in Technical Memorandum 98-2. Verbal approved was received from EPA in May 1998.

The "Navy Well," the Country Club Well, and the Honouliuli Well (2303-03) are actively used wells and therefore are continuously being purged. Samples are collected from the wells' sampling port located as close to the well head as possible. After ensuring that the wells have been recently pumping, the sampling port is opened and allowed to run for at least five minutes prior to sample collection.

The first quarterly samples were collected from the "Navy Well" and the Hawaii Country Club Well on October 22, 1997 and November 5, 1997, respectively. The "Navy Well" was sampled again in January 1998. The Hawaii Country Club well pump was being rebuilt in January 1998, thus, the well was sampled for the second time in February 1998. Both wells and the Honouliuli Well (2303-03) were sampled in May 1998 and July 1998. The HDOH collected split samples from the Country Club Well and the Honouliuli Well during these sampling rounds.

## 2.5 QA/QC Sampling

The following is a summary of the quality control (QC) samples collected during the RI. Internal (laboratory) and external (field) QC samples were used to monitor and quantify the performance of analytical methods and field procedures. Internal quality assurance (QA) samples were used to monitor and quantify the performance of the analytical laboratory. The use of internal QC samples is specified in the laboratory's QA program, which is addressed in the QAPP (Golder 1996c). External QC samples are introduced into the sample train in the field to monitor sample collection activities, shipping, and analytical performance.

The QC samples which were collected in conjunction with soil, sediment and groundwater sampling include the following categories of samples:

**Duplicate Samples**

Duplicate samples are samples that are divided into two or more portions at some step in the measurement process. Each portion is then carried through the remaining steps in the measurement process. A sample may be replicated in the field or at different points in the analytical process. For field-replicated samples, precision information is gained on homogeneity, handling, shipping, preparation, and analysis.

One sample in ten (10%) was collected in duplicate and designated for duplicate analyses. The total number of duplicate samples was distributed proportionately with the number of original samples to be collected at a specific site. Duplicate sampling was conducted in areas that were suspected to be contaminated or based on indications of contamination from field screening instruments, odors, or visual evidence. There was very little indication of contamination detected in the field; therefore, duplicate samples were often randomly selected based on the most probably areas of contamination.

**Trip Blanks**

Trip blanks pertain to VOC samples only because they are used to detect cross-contamination by VOCs. These blanks are prepared by the laboratory using analyte-free water before the sampling event, placed in the actual sample containers and are kept with the investigative samples throughout the sampling event, then packaged for shipment to the laboratory for analysis with other samples. One trip blank was included in each shipping container that contained samples for VOC analysis.

**Rinsate Blanks**

Rinsate blanks are samples collected by rinsing analyte-free deionized water through sample collection equipment after decontamination and placing the collected water in the appropriate sample containers for analysis. These samples are used to evaluate the adequacy of field decontamination procedures. The only equipment that was used to collected multiple samples was the point source bailor during Kunia well profiling and the Hydropunch sampler. An equipment blank was collected from both of these items.

**Matrix Spikes**

Matrix Spikes and Matrix Spike Duplicate samples are collected to evaluate the effect of the sample matrix on measurement accuracy and precision. One sample in twenty (5 percent) was collected and designated for matrix spike and matrix spike duplicate analyses. For soil samples, these duplicates were co-located at the laboratory within a single 6" sleeve, or obtained from the adjacent 6" sleeve to the primary sample if needed for adequate sample volume. For water samples separate samples bottle(s) were collected as required for each type of analysis.

# 3. ENVIRONMENTAL SETTING

## 3.1 Location and Topography

The Oahu Plantation is a 6,000 acre pineapple plantation located on the north-central plateau of the Island of Oahu (Figures 1-1 and 1-2). The facility is approximately 15 miles from the City of Honolulu, and the closest town is Wahiawa. Schofield Army Barracks and Wheeler Military Airfield are located in close proximity to the plantation.

The plantation is located within the Schofield Plateau physiographic province which is bounded on the east by the Koolau Mountain Range and on the west by the Waianae Mountain Range (Figure 3-1). The Schofield plateau was formed by the burial of older Waianae lavas by the younger lavas of the Koolau volcano. The surface topography of the plateau ranges from nearly flat near the central area around Wheeler Military Airfield (Figures 1-2 and 1-3) to steeply sloping, dissected terrain rising up to the mountain ranges east and west of the plateau. The crest of the plateau runs through Schofield Barracks and forms a natural drainage divide for the island. North of the divide watercourses flow to the north, and south of the divide they flow to the south to the west loch of Pearl Harbor. Narrow gulches dissect the plateau where streams have eroded the land surface.

The Oahu Plantation facility is an agricultural operation currently managed by DMFP. While comprising primarily agricultural areas, the facility also contains two company operated housing complexes (Kunia Village and Poamoho Village), equipment maintenance areas, chemical storage areas, warehouses, and administrative buildings. A fresh pineapple packing facility is located within the property boundaries.

The plantation can be geographically divided into two major sections: the Kunia Section and Poamoho Section (Figure 1-2) located on either side of the Schofield Plateau drainage divide and separated by an active military reservation, the Schofield Barracks. Pineapple production occurs in both sections. The northern section (Poamoho Section) is a relatively flat area located to the north of Wahiawa and Schofield Barracks. One of the company operated housing complexes (Poamoho Village) is situated adjacent to the northern section. The section is bounded by Wahiawa Reservoir (Lake Wilson) to the south, Kaukonahua Gulch to the east and Poamoho Gulch to the north. State Highways 80, 82 and 99 cross this parcel of land. The Poamoho Section is located approximately 3 miles north of the known source areas near the Kunia Well.

The southern parcel of land, which includes most of the areas investigated in this RI, is centered around Kunia Village (Figures 1-2, 1-3 and 1-4). The land in this parcel gently slopes to the east and southeast from a maximum elevation of about 1,200 ft to about 750 ft above mean sea level (amsl). The parcel is bounded by Waikele Stream Gulch to the north and by the Schofield Barracks and Honouliuli Forest Preserve to the west. State Highway 750 (Kunia Road) crosses through this parcel of land.

The Kunia section is the largest section of the plantation and contains the Kunia Well site. With the exception of 2 small Other Potential Source Areas, all of the known and

Other Potential Source Areas identified in the RI/FS Work Plan (ICF 1997) are located in the Kunia Section. The 1977 EDB Spill Area, and the Former Fumigant Storage and Mixing Areas are located within the Kunia section, and are collectively referred to in this document as the Kunia Village Area. As discussed further in Chapter 4 of this report, the results of the RI indicate that all of the known source areas for the NPL site are located within the Kunia Village Area of the Kunia section of Oahu Plantation.

A topographic survey was conducted of the Kunia Village Area as part of the RI and is shown in Drawing 1. The Spill Area and Kunia Well are situated atop relatively level ground at a surface elevation of about 850 ft amsl. Due to soil excavation activities in 1981, the Spill Area slopes gently to the north before dropping steeply approximately 30 ft to the Former Mixing Area. In 1983, approximately 16,000 tons of soil was excavated from the Former Mixing Area to remove soils impacted by COPCs. The excavated area was approximately 60 ft deep at the center, however, over the years sediments and fill material have reduced the total depth of the excavation. The soil removal activities resulted in near vertical side walls around the excavation pit. Immediately after the completion of excavation activities, a fence was constructed around the excavation area and the Former Storage Area to restrict access.

The entire fenced area around the pit (Figure 1-4) drains generally towards the excavation, which may fill with water during periods of heavy rainfall. An ephemeral watercourse (gulch), which drains upland areas including pineapple fields to the west, runs outside of the northern side of the fenced area and discharges through a culvert running underneath Kunia Road into previous pineapple fields and eventually to Poliwai Gulch and Waikele Stream.

The Poliwai Gulch is normally dry, covered with grasses and trees, and is bermed at the last pineapple field to prevent stormwater runoff. The distance from the fenced area to Waikele Stream is approximately 1.5 miles, and the distance from the confluence of Poliwai Gulch and Waikele Stream to Pearl Harbor is approximately 3.5 miles.

It is important to note that the DMC NPL site is typical of many large NPL sites where large tracts of land have been included as part of the Site by association with the site name although they do not necessarily pose a significant threat to human health and the environment. The nature and extent of any releases and potential threats that are posed are to be determined through the performance of the RI and BRA.

## 3.2 History and Summary of Previous Investigations

The following section summarizes the history and previous investigations related to the Del Monte Corporation (Oahu Plantation) site and is based on information presented in the RI/FS Work Plan (ICF 1997), Site Conceptual Model Technical Memorandum (ICF 1995b) and Data Summary and Evaluation Report (ICF 1995a).

### 3.2.1 Site History

#### 3.2.1.1 Overview

The Oahu Plantation has been used for the cultivation of pineapple since the early 1940s. Employees reside at Kunia Village, located in the southern section of the facility and Poamoho Village, located in the northern section (Figure 1-2.). From 1946 through April 1980, domestic and agricultural water was supplied to Kunia Village by the Kunia Well (State Well No. 2703-01). In the 1970s, the well served approximately 700 people.

On April 7, 1977, approximately 495 gallons of ethylene dibromide (EDB), a previously registered soil fumigant possibly containing 0.25% 1,2-dibromo-3-chloropropane (DBCP), was spilled on bare ground within 60 feet of the Kunia Well. The accidental spill occurred due to the failure of a hose connection on the supplier's (Dow Chemical Company) bulk transport container during transfer operations into an aboveground bulk storage tank. Photographic records from the Hawaii Department of Health (HDOH) indicated that the leading edge of the accidental spill reached the cement pad of the Kunia Well.

Following recommendations from the HDOH, the Spill Area was washed down with water based on the assumption that most of the EDB would volatilize. EDB was not detected above 0.5 μg/L in a sample collected from the Kunia Well one week later by the HDOH. Dow Chemical Company representatives also collected soil and water samples within a week after the accidental spill but did not transmit the results to DMC until after the contamination of the Kunia Well was discovered in 1980.

In 1979, in response to the detection of DBCP in groundwater in California near fumigated farmland, a joint groundwater sampling program was initiated by the Pineapple Growers Association of Hawaii and the State of Hawaii Departments of Agriculture and Health to assess the regional presence of DBCP in Hawaiian groundwater. Groundwater samples collected on April 14, 1980 from the Kunia Well indicated the presence of EDB and DBCP at levels of 92 μg/L and 11 μg/L, respectively. Groundwater samples collected on April 24, 1980 confirmed the presence of EDB and DBCP at levels of 300 μg/L and 0.5 μg/L, respectively. As a result, the Kunia Well was disconnected from the potable water system on April 25, 1980. Drinking water for the Kunia Village and DMFP workplaces is currently supplied by the "Navy Well" (State Well No. 2803-05), and since 1991 after approval by HDOH, by Del Monte Well No. #4 (State Well No. 2803-07) located approximately 1.5 miles north of the Kunia Well site.

Immediately after the discovery of contamination of the Kunia Well, DMC in cooperation with the State Departments of Agriculture and Health, conducted soils and groundwater investigations to estimate the nature and extent of impacts around the Kunia Well site. During the course of these investigations, other potential sources of contamination were identified. The three foci of potential contamination in the vicinity of the Kunia Well site were called the Spill Area, the Former Mixing Area, and the Former Storage Area (Figure 2-1). The Spill Area measures approximately 75 ft by 75 ft and lies near the Kunia Well.

The Former Mixing Area, measuring approximately 100 ft by 100 ft, is located approximately 100 ft north of the Kunia Well. Prior to removal in 1980, the Former Mixing Area contained one 10,000 gallon aboveground diesel tank, two 3,000 to 5,000 gallon aboveground D-D Soil Fumigant tanks, and one 25,000 gallon aboveground EDB bulk storage tank. In addition, the Former Mixing Area contained a small shed to store lindane prior to mixing with soil fumigants. In the past, EDB was mixed with diesel fuel to increase application volumes prior to application. The mixing activity took place near the 10,000 gallon aboveground diesel storage tank.

The Former Storage Area, approximately 120 ft by 100 ft, is located approximately 150 ft northeast of the Kunia Well. Between 1955 and 1975, EDB, DBCP, and D-D Soil Fumigant were stored on pallets in 30 to 55 gallon drums. The Former Storage Area consisted of a relatively small fenced area where EDB, DBCP and D-D drums were stored prior to transfer by pump into a truck mounted tank for mixing and field application.

As a result of soil investigation results, soil removal was conducted during two phases of excavation activities. In 1981, approximately 2,000 tons of soil were removed from the Spill Area. Soil sampling conducted after completion of this phase of soil removal indicated elevated levels of EDB and DBCP remained. As a result, a further 16,000 tons of impacted soil were excavated from impacted areas in the fall of 1983. The excavation created a 60 feet deep by 75 feet wide by 75 feet long excavation. Soil removal was terminated when perched groundwater infiltrated the excavation. Additional details regarding the soils investigation and removal activities are provided below in Section 3.2.1.2.

3.2.1.2 Soil Investigations and Removal Activities

Between 1980 and 1983, soil boring and groundwater investigations were conducted to estimate the extent of the impacts and to develop remedial actions based on source removal and containment. The description below is based on information provided in ICF (1997) which also provides figures and tables depicting sampling locations and results.

Between May 13, 1980 and May 29, 1980, seven borings were conducted (labeled as Boring Hole No. 1, 2, 3, 4, 5, 5A, and 5B) in the vicinity of the Kunia Well. A total of 45 soil samples collected from these seven borings were submitted for EDB and DBCP analysis. These boreholes extended to depths ranging from 50 to 165 feet bgs. The analytical results indicated that EDB was the predominant contaminant in the Kunia Well Spill Area and that the highest concentrations of EDB were found between 10 to 30 feet bgs.

In order to define the limits of the Spill Area impacts, the investigation was continued during the summer of 1980. Twenty-seven soil samples were collected from four soil boreholes drilled to depths of 52 feet bgs in the vicinity of the Former Fumigant Storage Area (labeled Boring Holes No. 6, 6S, 6M, and 9). The analytical results indicated the following:

- DBCP was the predominant chemical in the Former Fumigant Storage Area,
- The highest concentrations of EDB and DBCP were found between 30 to 40 feet bgs,
- Mean concentrations of EDB and DBCP from 0 to 20 feet bgs were 554 ppb and 1,728 ppb, respectively,
- Mean concentrations of EDB and DBCP from 20 to 50 feet bgs were 16,672 ppb and 51,079 ppb, respectively, and
- Chemicals had migrated into the perched groundwater.

An additional 31 samples were collected and analyzed in the summer of 1980 for EDB and DBCP from seven soil borings (6NA, 6C, 7, 8, 8A, 10, and 10A) north of the Former Fumigant Storage Area and from other locations on the periphery. The majority of these borings were conducted to 52 feet bgs, but two borings (7 and 8) were only to 14 feet bgs. The analytical results indicated that (a) EDB and DBCP were not detected in soil samples from 6NA, 6C, 8, 10, and 10A, (b) low concentrations of EDB (6.5 ppb) were detected in soil samples collected at shallow depths in Hole No. 7, which was located nearby pineapple fields to the north of the previous Former Fumigant Storage Area, and (c) EDB was detected at concentrations of 290 ppb in a soil sample collected from 40 to 43 feet bgs in Hole No. 8B; This borehole was located just to the south of the research building opposite the maintenance area for the plantation; this unusually high concentration was not confirmed by additional soil samples.

Between July and August 1981, roughly 2,000 tons of soil was excavated from the Kunia Well Spill Area. This excavation work occurred shortly after the former aboveground fumigant storage tanks had been permanently closed by removal. A minimum of 5 feet of soil material was excavated from the Kunia Well Spill Area. Numerous confirmation soil samples were collected in conjunction with this excavation work at 2 and 5 feet depth. In addition, limited grading of the Former Fumigant Storage Area was also conducted at this time with associated confirmation sampling also at 2 and 5 feet depth intervals.

In the summer of 1982, twenty test borings were drilled to depths ranging from 55 to 75 feet bgs in the vicinity of the Former Fumigant Storage Area and the Former Fumigant Mixing Area. Samples were collected at 10 feet depth intervals down each hole. Eleven of the borings were located in the area around Perched Well No. 6 and nine of the borings were located in the area around Perched Well No. 9. The highest concentrations of EDB were observed at from 35 to 65 feet bgs in the vicinity of the Former Fumigant Mixing Area while elevated concentrations of DBCP were detected between 25 and 35 feet bgs in the vicinity of the Former Fumigant Storage Area.

Between August and September 1983, an additional total of approximately 16,000 tons of soil was excavated. The material was removed from the Kunia Well Spill Area and the Former Fumigant Storage Area located between hole No. 6 and No. 9 where the highest levels of DBCP and EDB had been observed during previous soil sampling. A contractor operated bucket excavator was used to dig the large depression currently present. The

volume of material excavated was estimated by recording the number of truckloads of excavated material. The maximum depth of this excavation was approximately 60 feet, as measured from the edge of the pit closest to the Kunia Well. The excavation extended roughly 15 feet beneath the perched water table and extended over an area of roughly 5,000 square feet. Excavation activities were stopped after perched groundwater intrusion limited the excavator's ability to remove saprolite from the excavation site. Soil sampling was very difficult after excavation due to the depth of the perched groundwater at the bottom of the excavation pit. Thus only limited confirmation sampling was conducted from along the walls of the excavation.

Four soil samples collected from the sidewalls near the bottom of the excavation pit on August 8, 1983 were analyzed for EDB, DBCP, and total bromide. The results of the laboratory analysis indicated that (a) concentrations of EDB and DBCP in the soil were below the target level established by DMC for this work of 10,000 ppb, (b) EDB concentrations in saprolite at the bottom of the excavation pit ranged from 17.5 to 482 ppb, with an average of 152 ppb, and (c) DBCP concentrations in saprolite at the bottom of the excavation pit ranged from 7.5 to 421 ppb, with an average of 56.6 ppb.

Three soil samples were collected from the north, west and southwest walls near the bottom of the excavation pit on May 24, 1994 and analyzed to determine residual chemical concentrations. The analytical results indicated that DBCP concentrations were below detection levels in the western and southwestern walls of the excavation pit and was 67.2 ppb in the northern wall. EDB was detected in all soil samples in concentrations ranging from 18.6 to 27.8 ppb, with an average of 22.8 ppb.

In 1980 and 1983, the excavated soils were transported to and spread out over approximately 20 acres of field 8 located above the Army Road approximately 1,700 feet west of the Kunia Village. The soils were spread in thin layers (< 6 inches) to allow the chemicals to volatilize. This method of remediation was approved by the HDOH since EDB and DBCP were still registered for use in pineapple production. Cow manure was spread onto the area at a rate of approximately 20 tons per acre. The upper 18 to 24 inches of the soil was then disced prior to planting pineapples. Since land farming the soils, four pineapple harvests have occurred.

3.2.1.3 Groundwater Remedial Activities

During the course of the voluntary 1980 soil boring investigations, a previously unreported perched groundwater body was observed approximately 20 to 35 feet bgs in the vicinity of the Kunia Well. Three large diameter extraction wells (Perched groundwater wells No. 3, 6 and 9) were installed into the perched aquifer and pumped on a routine basis for sampling/analysis and remedial purposes.

Well No. 3 (completed at 106 feet bgs) was installed adjacent to the Kunia Well Spill Area; Well No. 6 (82 feet bgs) was installed within the Former Fumigant Storage Area; and Well No. 9 (79 feet bgs) was installed near the Former Mixing Fumigant Area. The three perched zone extraction wells were pumped once every two weeks or whenever sufficient groundwater had recharged the well. Between 1980 and 1983, perched water

samples were collected from the three monitoring wells on a weekly basis. Between 1983 and 1994, perched water samples were collected on a quarterly basis from Well No. 9 only. Limited sampling was also conducted from Well No. 3 between 1991 and 1994. Water was extracted from the wells during sampling events by use of dedicated 10 gpm submersible pumps. Well No. 6 was damaged during soil excavation activities conducted in 1983. A steady decrease in EDB and DBCP concentration was observed in perched well No. 3 and No. 9 over the fourteen years of monitoring.

Hydraulic properties of the saprolite aquifer were determined by conducting pumping tests in cased and uncased soil borings at the Kunia Village Area. The results of these pumping tests and the determination of perched aquifer hydraulic properties were reported in Mink (1980, 1982) and are summarized in Section 3.5.2.2.1.4 of this RI report.

Between 1980 and September 1994, the Kunia Well was pumped periodically to remove COPCs from the basal aquifer. Pumping occurred at the pump's rated capacity of approximately 300 to 325 gpm. The groundwater pumped from the Kunia Well was used for non-crop irrigation of a grass covered field approximately 350 ft north of the Kunia Well site. Water samples were routinely collected at the initiation of pumping and after four hours of pumping and were submitted to the DMC laboratory in Walnut Creek, California for EDB and DBCP analysis. Discussion of the results of these sample analyses are presented below in Section 3.2.3.1. DMFP stopped pumping the Kunia Well immediately after receiving a request from EPA to discontinue the activity on September 9, 1994 due to EPA's concerns about previous water disposal practices.

The Work Plan (ICF 1997) states that during the period when the Kunia Well was being pumped to remove COPCs from the basal aquifer (between 1980 and September 1994), the frequency of pumping was at least twice weekly for four to eight hours per day. At times, however, the frequency and duration of pumping was believed to have been greater. In order to more fully understand the quantity of water which was pumped from the well during this time period, DMFP personnel provided more detailed information regarding Kunia Well pumping history. Table 3-1 summarizes the estimated pumpage history for the Kunia Well as provided by DMFP (DMFP 1998g).

As seen in Table 3-1, the quantity of water pumped from the well varied from a maximum of about 32 million gallons per year to a minimum of about 5.5 million gallons per year. Generally, pumping exceeded at least about 10 to 12 million gallons per year, however. Pumping at this rate corresponds to about 10 to 12 hours per week, consistent with the statement in the Work Plan regarding the minimum frequency of pumping. In all but two years, however, the rate of pumping was significantly in excess of this amount, especially in the years immediately after 1980 when the frequency of pumping was on the order of 30 hours per week. Prior to 1980, when the well was used as a potable supply, pumping was on the order of 250,000 gallons per day. For comparison purposes, this corresponds to pumping approximately 90 hrs per week, or a continuous rate of 175 gpm.

### 3.2.2 History of Soil Fumigant and Pesticide use and Handling

A variety of previously registered chemicals have been used as pre-plant soil fumigants for control of parasitic nematodes in pineapples at the Oahu Plantation. These soil fumigants were typically injected into the soil to a depth between 12 and 18 inches just prior to a field being replanted with pineapples. An individual field was typically fumigated approximately once every four to five years. Between 1946 and 1983, the principal soil fumigant used on Oahu Plantation was ethylene dibromide (EDB). Other registered pre-plant soil fumigants previously used at the Oahu Plantation included D-D soil fumigant (a mixture of 1,2-dichloropropane, 1,3-dichloropropene, 2,3-dichloropropene, 3,3-dichloropropene, and traces of trichloropropane), 1,2-dibromo-3-chloropropane (DBCP), chloropicrin (trichloronitromethane) and Telone (which consists primarily of 1,3-dichloropropene). Methyl bromide was also used in small experimental quantities. Lindane (benzene hexachloride), an organochlorine insecticide, has also been used in combination with the soil fumigants.

Prior to the development of more efficient application pumps in 1974, EDB and other soil fumigants were often applied in conjunction with dilutants such as diesel fuel, to increase application volumes.

Application rates of the various soil fumigants varied widely. EDB was applied as a pre-plant fumigant to soil by chisel injection according to the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) label rate of between 6 and 12 gallons per acre once every four to five years. The current application rate of Telone II is within the FIFRA label application rate of 24 to 42 gallons per acre.

Heptachlor, Hyvar X (bromacil), Karmex (diuron), Nemacur 3 (fenamiphos) and Evik 80W (ametryn) were also used at the Oahu Plantation to maintain healthy crops. A brief description of the previous and current use of these chemicals follows.

<u>Ametryn</u>
Evik 80W ((Ametryn) 2-ethylamino-4-isopropyl-amino-6-methylthio-s-triazine) is registered for pre-emergence weed control in pineapple culture. It is one of the primary herbicides used on Oahu Plantation and throughout the Hawaiian pineapple industry for prevention of weed seed germination. Applications are made after mulching but before planting and after crop harvests. Applications to a given field area are made an average of once every 1.7 years.

<u>Bromacil</u>
Hyvar X (bromacil) (5-bromo-3-sec butyl-6-methyuracil) is registered as a post-emergence herbicide for control of weeds in pineapple culture. Hyvar X is one of the principal commercial herbicides used on Oahu Plantation and by other pineapple growers throughout the State of Hawaii. Applications may be made after mulching before planting and after crop harvests. Applications to a given field area are made once every 1.7 years.

Diuron
Karmex (diuron) (3-(3,4-dichlorophenyl)-1,1-dimethylurea) is as a pre-emergence herbicide for control of weeds in pineapple culture. It is one of the principal commercial herbicides used on Oahu Plantation and by other pineapple growers throughout the State of Hawaii. Applications to a given field are made once every 2.5 years.

Fenamiphos
Nemacur 3 (fenamiphos) (ethyl 3-methyl-4-(methyl-thio)-phenyl (1-methylethyl) phosphoramidate) is registered for preplant and postplant control of parasitic nematodes in pineapple culture. Fenamiphos is a principal postplant nematicide used on Oahu Plantation. It is an organophosphorous pesticide with high acute toxicity. Due to its high acute toxicity it is not considered as a potential human carcinogen. Applications are made at bimonthly to tri-monthly intervals up to 60 days before crop harvests.

Heptachlor
Heptachlor (1,4,5,6,7,8,8-heptachloro-3a, 4,7,7a-tetrahydro-4,7, methanoindene), previously used to control ants in pineapple culture, was canceled by EPA in 1982. Under the EPA cancellation agreement, Heptachlor inventories purchased prior to December 1982 and labeled for use in pineapple culture could be used until supplies were exhausted. Heptachlor was previously applied as foliar broadcast sprays after mulching immediately after planting (or 18 to 22 months before crop harvest). After the cancellation, several steps were used to reduce use and minimize risks. These included but were not limited to use of the lowest effective dosage, applications based on ant surveys, pineapple foliage not sold for animal feed, and applications made primarily infield along the edges of the field, reducing the total number of acre treated per year. In general, one application was made once every 2 to 3 years in a given field area. Heptachlor is no longer used on Oahu Plantation. In 1993 all Heptachlor use was voluntarily discontinued after tentative approval of an Emergency Exemption for infield use of Amdro (Hydramethylnon) on pineapple grown on Oahu was granted. In 1995, all of DMFP's heptachlor inventory was incinerated on a voluntary basis pursuant to RCRA requirements.

Soil fumigants were shipped to the Oahu Plantation in either 30-gallon or 55-gallon drums prior to 1973. Since the late 1950s, soil fumigant containers were stored near the Kunia Well at an area designated as the Former Fumigant Storage Area. Soil fumigant drums had been stored at a site located near Field 32 of the plantation prior to the late 1950s. After 1973, EDB was typically received from Dow Chemical Company in bulk shipments in Dow-owned transport trucks and stored in a 25,000-gallon aboveground storage tank located within 100 feet of the Kunia Well.

As mentioned previously, on April 7, 1977, approximately 495 gallons of EDB possibly containing 0.25 percent of DBCP was accidentally spilled on bare ground during transfer operations from a Dow bulk transport container. The spill occurred within about 60 feet of the Kunia Well due to a defective hose on the Dow bulk transport container. In addition, sporadic leakage of EDB and DBCP on bare ground in the Former Fumigant Storage Area and Former Fumigant Mixing Areas may have occurred over several decades. Both EDB and DBCP were stored in the Former Fumigant Storage Area in 30-

to 55-gallon drums. The quantity and duration of spillage at the Former Fumigant Storage Area and the Former Fumigant Mixing Area over the years are unknown.

### 3.2.3 Summary of Historical Groundwater Data

This sub-section summarizes trends in historical groundwater chemistry data at Kunia Village Area and selected regional wells, with the focus on EDB, DBCP and TCP. Complete summaries of groundwater data are included in ICF (1997).

#### 3.2.3.1 Kunia Village Area Basal Aquifer Data

**Kunia Well (State Well No. 2703-01)**

The Kunia Well is drilled to a depth of 976 feet below ground surface, is slotted over the lower 355 feet and is equipped with a pump rated at approximately 300 gpm. The depth to water is approximately 820 ft bgs.

After April, 1980 when the Kunia Well was disconnected from the potable water supply and until September 1994, the well was pumped periodically to contain basal aquifer COPCs (as discussed above in Section 3.2.1.3).

Historical data are available over the period when the well was being pumped. Table 2-1 of the RI/FS Work Plan (ICF 1997) presents a data compilation that was organized during earlier stages of the RI/FS process. In reviewing these data for this RI report, however, it became apparent that there were gaps in the data presented in the Work Plan, and some data were incorrect. Incorrect data included several relatively high EDB values attributed to the Kunia Well during the early 1990s that were, in fact, associated with perched aquifer wells. In order to correct these deficiencies, DMFP and Golder reviewed DMC's historical records and compiled a corrected data summary. The results of this data summary are presented in Appendix G. The discussion which follows below is based on the new summary of data presented in Appendix G.

Historical EDB and DBCP data exhibit a general trend of declining concentrations over the period 1980 to 1994. For EDB, after the initial detection of 300 $\mu$g/L on April 24, 1980, which was the highest value ever detected in the well, EDB concentrations ranged from non-detect to about 100 $\mu$g/L between 1980 and May 1982. Between May 1982 and August 1984, levels ranged from non-detect to about 15 $\mu$g/L except for one instance of 32.7 $\mu$g/L on April 11, 1983. After August 1984, levels were generally in the range of 0.1 to 1 $\mu$g/L. DBCP exhibits a similar downward trend although it is less pronounced than with EDB. Levels during the period April 1980 through July 1983 were generally in the range of 1 to 10 $\mu$g/L. After July 1983, levels were in the range of about 0.1 to 2 $\mu$g/L.

Concentrations of EDB and DBCP have typically been higher at the beginning of pumping than at the end of pumping (ICF 1997). This difference has declined significantly over the years however. Table 3-2 summarizes the average concentrations at the beginning and end of pumping for EDB and DBCP for each of the years 1980 through 1994. These average concentrations have been determined from the data

presented in Appendix G. On the basis of the data shown in Table 3-2, the following general observations are made:

- Concentrations for EDB and DBCP declined over the period 1980 to 1994. This decline occurred for beginning of pumping concentrations as well as end of pumping concentrations. For EDB, the average beginning and ending concentrations declined from about 50 and 1.4 $\mu$g/L, respectively, in 1980, to about .13 and .14 $\mu$g/L, respectively, in 1994. For DBCP the decline has been less dramatic but has also occurred. The average beginning and ending DBCP concentrations declined from about 5 and 1 $\mu$g/L, respectively, in 1980, to about 0.5 and 0.7 $\mu$g/L, respectively, in 1994.
- Most of the decline in concentrations occurred during the period 1980 through 1984. This corresponds to the time during which source removal activities took place at the Kunia Village Area.
- In addition to the general decline in concentrations, the ratio of the beginning to ending concentration has also declined and is now equal to about 1 for both compounds. For EDB, the ratio was about 36 in 1980. After 1986, the ratio was about one for every year except 1989 and 1990. After 1990, the ratio was one for every year. For DBCP, the ratio declined from about five in 1980 to one by 1982. The ratio for DBCP has been equal to about one for every year since 1983.

Therefore, concentrations have declined significantly since 1980 for both EDB and DBCP. In addition, the effect of pumping, while significant for both compounds during the early 1980s, was no longer significant for either compound after about 1990. Additional discussion of the significance of these observations with regards to the issue of the Kunia Well as a potential conduit is presented in Chapter 5.

Limited trichloropropane (TCP) testing of groundwater samples from the Kunia Well, conducted by the Del Monte Corporation in the mid 1980s, indicated low concentrations of TCP. Three analyses conducted in the 1990s by Hawaii Water Resources Research Centre measured a range in TCP concentrations from 0.53 ppb in September, 1991 to 0.35 ppb and non-detect in June, 1994.

3.2.3.2 Regional Basal Aquifer Data

This section presents a summary of known historical organic chemical impacts in the basal aquifer of south-central Oahu. The information provided below is based primarily on Lau (1987). Additional data for the period after 1987 were obtained directly from the HDOH Safe Drinking Water Branch files.

As discussed further below in Section 3.5, the Pearl Harbor Basal aquifer in southern Oahu lies within basalt flows of the Koolau and Waianae volcanic formations. Koolau basalts overlap above the older, eroded basalts of the Waianae volcano. The general flow of groundwater within the Koolau portion of the Pearl Harbor aquifer is to the south toward Pearl Harbor. Flow in the Waianae portion is believed to be to the south-southwest. In the area of the unconformity between the Koolau and Waianae formations, there is a head drop indicating that groundwater flow is from the Koolau to

the Waianae but not in reverse. The approximate location of the unconformity in Central Oahu separating the Koolau and Waianae basalts is shown in Figure 3-2.

In Central Oahu, previous agricultural uses of EDB, DBCP and D-D Soil Fumigant (containing 1,2,3-trichloropropane and 1,2-dichloropropane) may have contributed to regional occurrences of DBCP and TCP in the Pearl Harbor Aquifer. Surveys of previous soil fumigant uses completed by the Hawaii Department of Agriculture indicated that:

- For many years, Dole Package Foods and Libby Corporation grew pineapple in large portions of the eastern side (or Koolau side) of the Central Oahu Plain. Much of the former pineapple growing areas have been eliminated due to urban development, such as in Pearl City, Mililani, Waipio, Waipio Acres and Crestview. Similarly to the Oahu Plantation, Dole and Libby fields were treated with preplant soil fumigants to control parasitic nematodes. The principal soil fumigants used by Dole and Libby consisted of combination treatments using D-D Soil Fumigant, Telone and DBCP. Lindane in combination with other registered soil fumigants was also used by Dole and Libby.
- As previously discussed, the Del Monte Corporation grew pineapple on the western side (or Waianae aquifer side) of the Central Oahu Plain. This area continues to be used for pineapple production today. The principal soil fumigant used by DMC was EDB. D-D Soil Fumigant and DBCP were also used but only on a limited basis.
- Due to higher rainfall, higher application rates, and the persistence of chemical constituents in the D-D Soil Fumigant and DBCP mixtures, the eastern (or Koolau) portion of the Pearl Harbor Aquifer may have been more prone to groundwater impacts from agricultural uses of soil fumigants.

Sampling of wells associated with the Koolau area of the aquifer has been done since approximately 1977. With the exception of the Kunia Well and the Hawaii Country Club Well, sampling of wells within the Waianae aquifer has been more limited. Sampling results have indicated that there are regional occurrences of DBCP, TCP, and EDB on Oahu which are associated with sources other than the Kunia Village Area and agricultural uses on the Oahu Plantation (Figure 3-2).

- There are historical occurrences of DBCP and TCP in a series of Mililani area wells (northern Pearl Harbor aquifer) near former Dole and Libby pineapple agricultural areas.
- Waipahu area wells located at the southern portion of the aquifer and within one mile west of several large volume spill sites associated with a Navy fuel pipeline were found to have detectable levels of EDB and TCP. Due to the proximity of the Waipahu wells to the pipeline and the lack of detectable levels of EDB in wells to the north, the source of the EDB is believed to be fuel that has leaked from the pipeline.
- Wells west and south of the Waipahu wells have been found to contain TCP but no other contaminants.

The Hawaii Country Club (HCC) well is located 1.5 miles south of the Kunia Village Area, and is the nearest basal well which is potentially downgradient of the Oahu Plantation. Samples taken from this well did not indicate the presence of EDB, DBCP, or TCP above the detection levels of 0.1 μg/L, 0.05 μg/L, and 0.2 μg/L, respectively, until 1993 when DBCP was first detected. Sampling during the late 1980s was infrequent, however. Lau (1987) reports detection of DBCP in this well prior to 1987 but review of the data revealed it to be below the detection limit. Samples collected at this well by HDOH and the Water Resources Research Center at the University of Hawaii have contained DBCP at concentrations of 0.04 μg/L to 0.074 μg/L in samples analyzed since 1993. Samples collected during March, April, July and November 1997 and April and May 1998 by the HDOH all contained detectable DBCP at levels between 0.06 to 0.074 μg/L. EDB and TCP have not been detected at this well at levels above the detection limit. HDOH has reported non-quantifiable (NQ) detections for TCP and EDB at the HCC well in samples collected since October 1996. These results represent possible detects below the quantitation limit. Results of recent analyses at the HCC well are shown in Table 3-3.

The Kunia II wells are Honolulu Board of Water Supply (BWS) wells located 4.1 miles south and slightly east of the Oahu Plantation and within one mile southwest of former Libby and Dole pineapple fields (ICF 1997). Low levels of DBCP and elevated levels of TCP were detected in these wells as early as 1983. No DBCP has been detected in these wells since the mid-1980s, however, there have been a number of NQ results (possible detections below the quantitation limit). TCP continues to be observed in these wells at levels of approximately 1 μg/L. No EDB detects or NQ detections have ever occurred in these wells, including samples collected as recently as November 1997. Historical data for the Kunia II wells since 1990 are summarized in Table 3-3.

The likely source of the observed chemicals at the Kunia II wells is the past agricultural practices at the nearby Dole and Libby pineapple fields (ICF 1997). The presence of DBCP at the Kunia II wells was first observed in 1983 which is believed to be much earlier than could have occurred if the chemical was associated with a potential release from the Kunia Village Area, based on groundwater velocity and travel time estimates presented in Chapter 5. This first occurrence is also much earlier than the first observed occurrence at the HCC well which (if they are in the same aquifer) would potentially be located along the same downgradient flowpath from the Kunia Village Area. TCP has never been detected at the HCC well. The levels of TCP observed at the Kunia II wells are approximately equivalent to those observed in the Kunia Well despite separation of approximately 4.5 miles. Finally, as discussed further in Section 3.5 below, the Kunia II wells are in the Koolau aquifer which is hydraulically separated from the Kunia Village Area.

Kunia I wells are located about 5.2 miles south of the Kunia Village Area. Review of HDOH data for these wells indicates that since 1991, no EDB or DBCP detections have occurred. It is not known if monitoring data are available for the period prior to 1991. TCP analyses conducted during 1997 indicated TCP is present in these wells at approximately 0.7 to 0.8 μg/L (Personal Communication, Chester Lao, BWS). Data obtained from the HDOH for these wells are shown in Table 3-3. As with the Kunia II

wells, the Kunia I wells are in the Koolau aquifer which is hydraulically separated from the Kunia Village Area.

Honouliuli I and II wells, located 4.7 and 4.4 miles south of the Kunia Village Area, respectively, are the nearest drinking water wells to the Oahu Plantation within the Waianae aquifer. Sampling of these wells has not revealed any detectable or NQ levels of EDB, DBCP, or TCP since sampling began in 1989. This includes data collected as recently as July 1998 as part of this RI. The Honouliuli I wells have been out of service since 11/9/92 due to high chloride content. Table 3-3 summarizes data for these wells from HDOH.

Sampling conducted at other wells within the Waianae aquifer (prior to 1987) also has not detected EDB, DBCP, or TCP (Figure 3-2; Lau (1987)). Only a limited number of wells in the Waianae aquifer are reflected, however, in the Lau (1987) report.

In general, EDB, DBCP, and TCP have been detected in the Kunia Well at the Kunia Village Area and DBCP and TCP have been detected in samples taken in the northern area of the Dole plantation. Samples collected at wells south of both plantation sampling sites have had no detectable levels of EDB with the exception of the Waipahu wells approximately eight miles southwest of the Dole sampling site. The Waipahu wells lie within one mile of a Navy pipeline that has experienced significant fuel spills during the 1950s, and as recently as 1978. Wells located between both the former Dole and DMC sampling sites and the Waipahu wells indicate no detectable levels of EDB. TCP alone has been detected in several wells in the southernmost portion of the Koolau aquifer. Wells located west of the Koolau-Waianae unconformity and assumed to represent the Waianae aquifer have had no detectable levels of EDB, DBCP, and TCP.

On the basis of the information presented above, the following general conclusions can be made:

- There is a regional history of DBCP/TCP occurrence in the northern Pearl Harbor aquifer associated with past agricultural practices in the general Mililani area of Oahu. The occurrence of DBCP/TCP in the Mililani area may extend south to the vicinity of Kunia II wells. South of the Kunia II wells only TCP is observed.
- There is an isolated area impacted by EDB in the Waipahu area believed to be related to fuel leaks from a military pipeline. Other than this area and the Kunia Well site, there are no observable areas of EDB impacts in basal groundwater in Central Oahu.
- The Hawaii Country Club well is believed to not have been impacted prior to 1993 as no sampling results were greater than the detection limits until this time. Sampling was infrequent during the late 1980s however. After 1993, DBCP has been periodically detected. EDB and TCP have not been detected above the detection limit, although recent results have included several NQ values.
- Water quality impacts at the Kunia I/II wells (DBCP and/or TCP) are believed to be associated with former Dole or Libby pineapple fields to the northwest, based

on the timing of impacts, the location of the wells in the Koolau area of the aquifer, and groundwater flow directions.

- No impacts have been observed in Honouliuli I/II wells or other Waianae wells south of Honouliuli, although it is acknowledged that limited data for these wells are available. The Honouliuli II wells, however, have been sampled as recently as July 1998.

3.2.3.3 Perched Aquifer Data

**Perched Aquifer Well No. 3**

Perched aquifer well No. 3 is located within the Spill Area and is drilled to a total depth of 106 feet below ground surface. The well was pumped and sampled from February 1981 through May 1982 and again from 1993 until September 1994, when pumping was ceased at EPA's request. Between 1983 and 1992 the well was neither pumped nor sampled due to insufficient recharge rates (ICF 1995a).

Before pumping began in February, 1981, EDB and DBCP concentrations were analyzed at 317 µg/L and 0.7 µg/L respectively. Shortly after pumping, on May 8, 1981, a maximum EDB concentration of 433 µg/L was reported. Since this time, EDB concentrations have declined to less than 62 µg/L during 1982. Samples collected in May 1993, after ten years of not pumping, indicated EDB concentrations of 0.16 µg/L. DBCP was not detected. In April 1994, both EDB and DBCP were below the 0.02 µg/L detection limit.

**Perched Aquifer Well No. 6**

Perched aquifer Well No. 6 is located in the Former Fumigant Storage Area and is drilled to a total depth of 82 feet below ground surface. Groundwater samples were collected from this well between 1980 and 1982. After 1982, recharge to the well was insufficient to maintain pumping (ICF 1995a).

A maximum EDB concentration of 98,300 µg/L was detected in a December, 1981 sample taken approximately ten months after pumping began. In March 1982, EDB and DBCP were detected at 13,750 µg/L and 9,060 µg/L respectively. By May 1982, EDB concentrations were reported at 960 µg/L.

**Perched Aquifer Well No. 9**

Perched aquifer Well No. 9 is located in the Former Fumigant Mixing Area and is drilled to a total depth of 79 feet below ground surface.

Initial EDB and DBCP concentrations were measured at 235,000 µg/L and 5,000 µg/L, respectively (ICF 1995a). After initiation of the pumping program, EDB and DBCP concentrations decreased by up to two orders of magnitude. Between 1984 and 1991, EDB and DBCP concentrations averaged 7,062 µg/L and 86 µg/L, respectively.

Groundwater samples collected between 1993 and 1994 indicated average EDB and DBCP concentrations of 21.5 μg/L and 1.07 μg/L, respectively.

## 3.3 Meteorology

The Island of Oahu, which lies a little south of the Tropic of Cancer and within the belt of northeast trade winds, is characterized by moderate temperatures that remain relatively constant throughout the year. A climatic data summary for Honolulu, the nearest station for which a wide range of climatic data are available, is shown in Table 3-4. The mean annual temperature near sea level at Honolulu is 77.2° F. The lowest temperature ever recorded there is 53° F and the highest, 95° F. The average daily range in Honolulu is about 14° F. January and February are the coldest months and average about 73° F, and August is the warmest at about 81° F. The decrease in temperature with increasing altitude is about 3° F per thousand feet. Temperatures at Oahu Plantation would therefore be expected to be about 3° F cooler than at Honolulu.

The mean maximum relative humidity in Honolulu is about 76% and the mean minimum is 59% (Visher and Mink 1964). The mean wind speed is 11.3 mph, and the prevailing wind direction is east-northeast, the direction of the trade winds.

In general, two patterns of air mass circulation predominate on the Hawaiian Islands: the dominant anti-cyclonic pattern that produces the trade winds, and the less frequent cyclonic pattern which results in southerly winds and humid weather referred to as Kona weather. The trade winds pattern is produced by a stable high pressure system established north of the islands. When this high-pressure breaks down, it is replaced by a cyclonic pattern and by an intruding low-pressure air mass, which is accompanied by frontal activity (Visher and Mink 1964). The anti-cyclonic or trade winds pattern predominates about two-thirds of the time and the cyclonic pattern or a mixed pattern, one-third. The anti-cyclonic pattern occurs throughout the year but is more prevalent in the summer months than the winter. The cyclonic pattern is much more common in winter than summer.

As shown in Figure 3-3, rainfall on Oahu is as little as 20 inches on the extreme leeward (or western) coast and as much as 300 inches at the crest of the Koolau Range. In general, rainfall decreases progressively from the mountains to the sea.

Trade-wind or anti-cyclonic circulation results in greater amounts of rainfall on windward Oahu than leeward Oahu. Rainfall in the Waianae Range is considerably less than the Koolau Range because the trade-wind air has lost much of its moisture to the Koolau Range before it reaches the slopes of the Waianae Range. Cyclonic circulation (Kona weather) on the other hand provides a more uniform distribution of rainfall throughout the island. Most of the rainfall in the drier regions is associated with cyclonic storms. As a result, the dry leeward areas have relatively wet winters and dry summers. In contrast, the Koolau Range and higher parts of the Waianae Range have heavy rainfall year round.

The occurrence of groundwater resources on Oahu is the direct result of rainfall infiltration. Due to the much higher amounts of rainfall in the Koolau Range as compared to the Waianae Range, most of the recharge to basal groundwater is associated with the Koolau Range.

Table 3-5 summarizes rainfall during the last 15 years for the Kunia Village Area. The data are for a rain gauge located at the Kunia Well site. Average rainfall for the Kunia Village Area is about 36 inches per year (DMFP 1998e), with October through March the wettest months at about 4 to 5 inches per month, and April through September the driest months at about 1 to 2 inches per month.

As seen in Table 3-5, over 50 inches of rain fell during a period of prolonged Kona weather storms from November 1996 through March 1997. This resulted in an exceptionally high stormwater level in the excavation pit.

The evaporation rate is high. HLA (1996) report about 75 in per year for the Schofield Barracks area. The average monthly potential evaporation exceeds average monthly rainfall from about April through October. Oki (1998) reports approximately 70 to 80 inches per year pan evaporation for the Kunia, Hawaii vicinity.

## 3.4 Surface Water

No permanent streams, springs, seeps or natural surface water bodies exist or were identified during the RI within at least 2 miles of the Kunia Well site. A 2.4-million gallon man-made irrigation basin is located within the plantation roughly one mile to the northwest of the Kunia Village (Figure 1-3). The nearest permanent (natural) surface water body is Lake Wilson (Wahiawa Reservoir) located approximately 3 miles northeast of the Kunia Well site.

Stormwater run-off from the northern section of the Plantation (centered near Poamoho Village) flows into two deeply incised stream gulches (Poamoho and Kaukonahua) which ultimately drain to the north near Waialua. No well developed drainage pattern has been established within this relatively flat area.

Stormwater run-off from the southern section of the Plantation flows into a series of southeasterly trending ephemeral drainage gulches (Manuwaiahu, Huliwai, Ekahanui, as well as some which are un-named) which combine into Poliwai Gulch and ultimately feed into Waikele Stream (located approximately 2.5 miles SE of the Kunia Well site), which flows directly south and discharges into Pearl Harbor (approximately 5.5 miles south of the Kunia Well site) (Figures 1-2 and 1-3). These gulches are dry throughout much of the year and only flow during, and for a short time after, periods of heavy rainfall.

At the Kunia Village Area, an un-named ephemeral gulch skirts the northern fenced boundary of the pit area and flows through a culvert under Kunia Road, eventually discharging into Poliwai Gulch, and Waikele Stream (Figures 1-2, 1-3 and 2-14). This ephemeral gulch flows only intermittently, during periods of heavy rainfall. A narrow

ravine, located between the Kunia Well and Kunia Road (Figure 1-4), does not represent a distinct stormwater drainage path (as described in the RI/FS Work Plan (ICF 1997)). No stormwater flow was observed from the ravine even during the exceptionally high rainfall which occurred during RI sampling.

It is important to note that water which periodically flows in the ephemeral gulch north of the pit area is not representative of, or continuous with, the perched groundwater at the Kunia Village Area. Previous investigations have indicated that streams on the Schofield Plateau do not lose large volumes of water to groundwater, nor do they gain from groundwater (HLA 1996). Leakage of groundwater contributes little, if any, to streamflow, and surface water streams in the region are believed to contribute little recharge to groundwater, primarily because of the low-permeability clay-rich soil (Dale and Takasaki 1976). Water level measurements in the pit area collected in piezometers and monitoring wells during this RI confirm that waterflow in this gulch is not comprised of perched groundwater discharge as the perched groundwater levels were much lower than the ephemeral gulch bed elevation.

Under normal circumstances, surface water in the pit area drains towards the pit, and the pit fills during periods of heavy rainfall. However, during unusual rainfall events, such as were observed at least once during the RI, the level of water in the pit can rise high enough where it spills out of and discharges from the pit area to the ephemeral gulch. The location of the overflow point is the northeast corner of the fenced area (Figure 1-4). An earthen berm was constructed (after approval by EPA) to prevent future stormwater discharges from the excavation pit area. Backfilling of the pit will be considered in the remedial evaluation process in the FS.

## 3.5 Geohydrology

The regional and local geohydrologic setting of the Kunia Village Area are presented in this section. The discussion is based on available technical literature, and the field investigative activities conducted as part of the RI. All geologic and hydrogeologic data collected in the RI are presented in this section. The results of chemical analyses performed on samples of environmental media are presented in Chapter 4. The fate and transport of chemicals identified in Chapter 4 is addressed in Chapter 5.

It is important to note that the discussion of local geohydrology included in this section is focused primarily on the Kunia Village Area only. Most drilling activities, and all groundwater-related activities, were focused on this area. Borings at Other Potential Source Areas did not exceed 25 ft depth, and most were less than 15 ft. Perched groundwater was not encountered in any of these borings. Boring logs for all of the Other Potential Source Area borings are included in the relevant data appendices, but there is no detailed discussion herein of the geologic or hydrogeologic conditions observed at these locations. In addition, and as discussed further in Chapter 4, except for one occurrence of petroleum hydrocarbons, no chemicals above regulatory based screening criteria were detected at any sampling locations outside of the Kunia Village Area.

### 3.5.1 Regional Geologic Setting

The Hawaiian archipelago is located near the middle of the Pacific Plate, a large piece of the earth's crust which is migrating to the northwest relative to a stationary "hot spot" or zone of magma upwelling located within the earth's mantle. This upwelling has produced a series of Tertiary age shield volcanoes associated with cracks or rift zones in the crust. The islands consist of the emerged peaks of these volcanoes, and extend in a northwesterly direction for a distance of some 1,600 miles from the island of Hawaii to Kure Island. Volcanism is active on the island of Hawaii, and the age of the rocks becomes progressively older to the northwest.

#### 3.5.1.1 Bedrock Geology

The fluid lavas of the Hawaiian Islands build broad, gently sloping cones of domical or ellipsoidal shape, built by the eruption of many thousands of thin basaltic lava flows from zones of fracturing known as rift zones. Typically, Hawaiian shield volcanoes are broad and flat in profile. The original surfaces of the domes had slopes of about 3-10 degrees (Visher and Mink 1964). The extrusion of the immense quantities of lava associated with the domes eventually caused isostatic adjustment and downbowing of the crust in the vicinity of the Hawaiian volcanic ridge.

The Island of Oahu is comprised of the remnants of two late Tertiary shield volcanoes and their associated rift zones (Figure 3-1). The western part of the island is the eroded Waianae volcano (about 3 million years old), which was the first of the two volcanoes to emerge above sea level; the eastern part of the island consists of the eroded dome of the Koolau volcano (about 2 million years old). The Waianae dome, because of its earlier emergence, was deeply eroded before the Koolau dome reached its maximum height. Piling up of lavas from the Koolau dome against the eroded lower slopes of the Waianae dome eventually produced the broad gently sloping feature in the central area of Oahu called the Schofield plateau (Figure 3-1). Although some inter-fingering of Waianae and Koolau basalts is thought to have occurred, the bulk of the Koolau basalts rests upon the weathered flank of the older Waianae volcano.

The rift zones (Figure 3-1) are characterized by a concentration of sub-vertical dikes through which basalts were extruded at the surface. Near the vents the lavas are predominantly pahoehoe, but a'a becomes more abundant at greater distances. Pahoehoe flows are characterized externally by smooth, hummocky, ropy, or festooned surfaces, and internally by lava tubes and nearly spherical vesicles. A'a flows are characterized by a central massive phase lying between clinkery fragmental top and bottom layers (Wentworth and MacDonald 1953).

The dominant lavas of Hawaii are basalts. Ash and tuff are not abundant generally. The bulk of the Island of Oahu is comprised of dike-free basalts formed by sub-aerial lava flows which make up a gently-dipping stratified aquifer fabric. These layers rest upon a base of submarine-extruded, relatively impermeable pillow basalts which, because of subsidence of the island, are now at a depth of over 2 km below sea level (Andrews and Bainbridge 1972).

The Koolau volcanic series consists of gray, blue, red and black jointed, dense to very vesicular, aphanitic and porphyritic basalts extruded in short and long, interbedded pahoehoe and a'a flows 10 to 80 ft thick (Stearns 1939). The pahoehoe flows occur chiefly near the crest and are thin-bedded and vesicular, typically less than 10 ft thick. The a'a flows are thicker and consist of dense, massive, and slightly vesicular basalt intermixed with clinker zones. A'a flows with their clinker beds make up about 60% of the range. The basalt exceeds 3,500 ft in thickness, and the dip of the lavas is generally less than 10°.

The Waianae volcanic series consists of lower, middle and upper members. The lower member consists of aphanitic and porphyritic pahoehoe basalts with minor amounts of a'a, varying from 10 to 200 ft in thickness; the middle member consists of nearly equal amounts of pahoehoe and a'a; and the upper member is comprised primarily of a'a. The total thickness of the lavas exceeds 4,000 ft (Stearns 1939).

After volcanic activity ceased at the end of the Tertiary and the island began to subside, terrestrial and marine sediments were deposited around the perimeter of the island to form a flat coastal plain on the island's southern coast (Figure 3-1). Changes in sea level, caused by isostatic adjustment and the building and melting of glaciers in colder regions during Pleistocene time, influenced the development of this coastal plain. The changes in sea level were accompanied by the growth of coral reefs and marine sedimentation. Today the fossil coral reefs and marine and terrestrial alluvial sediments constitute the bulk of the coastal plain deposits. These sediments form a relatively impermeable wedge (referred to as "caprock") over the highly permeable lavas (Visher and Mink 1964).

3.5.1.2 Surface Geology

A geologic map of the Kunia Village Area vicinity is shown in Figure 3-4. As seen in the figure, surficial materials mapped in the vicinity include Waianae basalts to the west, Koolau basalts to the east, and "consolidated noncalcareous deposits" directly underlying the Kunia Village Area. The surface contact of the Waianae basalts is some 4000 ft to the west of the Kunia Village. The dip of the Waianae basalts located to the west of the Kunia Village Area is variable, but is generally about 8°.

The consolidated non-calcareous deposits shown in Figure 3-4 consist of older alluvium and colluvium derived from the adjacent slopes of the Waianae Range, and of the weathered remnants of the original basalt surface. In situ decomposition of basaltic bedrock has progressed to depths of approximately 100 to 200 ft bgs, resulting in the formation of residual surface soil (completely weathered basalt) underlain by saprolite (highly weathered basalt).

Near surface materials consist generally of a deep-red lateritic soil (lithosol) having a loose, and generally porous structure. The surface soil extends to the base of the tillage zone at about 2 to 3 ft. Organic carbon is abundant in the surface soil. The surface soil is part of the Kunia Series of the Ustoxic Humitropept subgroup formerly called low humic latasols (Mink 1981).

Underlying the surface soil is the subsoil, which extends to depths of about 10 to 30 ft. The subsoil is similar to the surface soil in texture and mineralogy but has larger and more distinct structural units. It is very low in organic carbon. The soil layer is typically a dark reddish brown silty clay while the clay subsoil is typically a lighter red to tan clay. Both soil and subsoil represent complete chemical and textural breakdown of the original rock.

The subsoil grades with depth to saprolite, which is a highly weathered basalt that retains some textural and structural features of the parent rock, such as vesicles, fractures and relict minerals. Saprolite is a clay-rich thoroughly decomposed rock formed by in-situ weathering of the basalt. Typically, saprolite is logged as a silt when described from drill cuttings because the textural features are not apparent after drilling. Beneath the saprolite lies basalt. In places, the basalt immediately beneath the saprolite may exhibit some moderate weathering. This zone of weathered basalt is a transitional zone between the highly weathered saprolite and fresh basalt.

As basalt weathers to saprolite, its pore structure is altered and, generally, permeability is decreased as secondary clay minerals fill in pore spaces. In some areas, the permeabilities are low enough to create locally perched water tables within the saprolite zone. Boulders of relatively unweathered basalt are locally encountered within the saprolite. These boulders are thought to represent remnants of massive portions of lava flows (Stearns and Vaksvik 1935). The saprolite generally has a thickness of about 50 to 150 ft.

In the vicinity of the Kunia Village Area, this sequence of surface soil, subsoil and saprolite is typical and generally mantles the basalt which is encountered at depths of approximately 150 to 200 ft below ground surface (bgs). Beneath the saprolite lies the moderately weathered basalt and basalt, which comprises the remainder of the unsaturated zone and basal aquifer. The distribution of soil and rock is highly erratic because of the highly variable nature of individual lava flows. A generalized stratigraphic column for the region is shown in Figure 3-5.

The saprolites of the Kunia Village Area are believed underlain by basalts of the Koolau volcanic series, given the location of the surface contact of the Waianae some 4000 ft to the west (Figure 3-4). The contact between the Koolau and Waianae basalts would therefore exist at depth beneath the Kunia Village Area. The depth to the contact between the basalts, however, has not been previously defined for the Kunia Village Area. Section 3.5.2.2.2.5 includes a discussion of the depth to the contact and the presence of Koolau/Waianae basalts beneath the Kunia Village Area.

### 3.5.2 Hydrogeology

#### 3.5.2.1 Regional Hydrogeology

Groundwater provides essentially all municipal and domestic water on Oahu, as well as most of the irrigation water. The majority of this water is derived from the basal volcanic aquifer located beneath central and southern Oahu, the Pearl Harbor Basal Aquifer,

comprised of Koolau and Waianae lavas. The layers, generally a few feet to tens of feet thick, form a matrix of thin overlapping tabular units tens to hundreds of feet wide and up to 10 miles long that dip about 5 to 10 degrees to the ocean. These layers rest upon a base of relatively impermeable submarine-extruded pillow basalt, which could exist to a depth of about 2 km. In addition to the basal aquifer, other aquifers of note include the dike-impounded water bodies, such as the Koolau and Waianae Dike-impounded Water Bodies within their associated rift zones, the Schofield High-level Water Body, and locally, perched shallow groundwater lenses within saprolite.

3.5.2.1.1 Hydrogeologic Units

3.5.2.1.1.1 Basal Groundwater

The most extensive bodies of freshwater on Oahu occur as basal groundwater. Basal groundwater occurs when fresh water percolates into the saturated zone and displaces the underlying sea water (Figures 3-6 and 3-7). The accumulating fresh water forms a lens-shaped body with a surface that extends above the surface of the salt water due to the contrast in densities between freshwater and sea water. An intervening transition zone occurs between the two zones containing a water of intermediate salinity. This phenomenon is referred to as the Ghyben-Herzberg principle, and these lens-shaped fresh water bodies are often referred to as Ghyben-Herzberg or basal lenses. The water table or potentiometric surface of a basal-water body is typically rather flat and is no more than several feet to several tens of feet above sea level. The predominant volume of the freshwater body lies below sea level.

The lavas from the Koolau volcano have the greatest areal extent on Oahu (Figure 3-4) and comprise the largest and most significant aquifers. Lavas from the Waianae volcano are also important aquifers. The permeability of the unweathered rock that makes up the basal aquifers is generally high. The principle flow structures contributing the high permeability are clinker layers associated with a'a, lava tubes in pahoehoe, irregular openings between and within the flows, and contraction joints (Visher and Mink 1964). Because most of the features which contribute to permeability lie parallel to flow surfaces, the stack of tabular units may be several orders of magnitude less conductive vertically than horizontally. Vesicles which make up a large part of the total volume of the lavas and contribute greatly to the porosity, are seldom interconnected and have little effect on permeability. Connected porosity (through which water may flow) is believed to be generally less than 10% (Voss and Wood 1993).

Weathering of the basaltic rock causes a decrease in the sizes of openings and a reduction in permeability. This loss in permeability may extend to a depth of 50 to 100 ft below the surface of the basalt (Visher and Mink 1964).

The Pearl Harbor Basal Water Body (Figure 3-8 and 3-9), comprised of lava flows associated with the Koolau and Waianae rift zones, serves as a primary source of potable and irrigation water for Honolulu and the island. The entire area from Manoa to the Waianae Crest and from the caprock wedge to the Schofield High-water zone is a single, though geometrically complicated, basal aquifer. For convenience only, the portion of

this aquifer east of Red Hill is sometimes termed the Honolulu Aquifer although it is hydraulically continuous with and a part of the Pearl Harbor aquifer. The layout and nomenclature of the aquifer systems and sectors is shown in Figures 3-10 and 3-11.

3.5.2.1.1.2 Dike-Impounded Groundwater Bodies

In and near the rift-zones of the Koolau and Waianae volcanoes, many dikes cut across the layered lava flows, and in places the dikes nearly completely displace the layered rock (Figure 3-7). In other areas, they are widely spaced and form compartments enclosing large masses of permeable lava (Figure 3-9). The dikes are generally nearly vertical, and they are dense and of low permeability. Because of their low permeability, the dikes impound groundwater in many of the compartments they enclose in the central parts of the Koolau and Waianae Ranges and perhaps under the Schofield plateau.

One possible dike-impounded body is the Wahiawa Aquifer, often referred to as the "Schofield High-level Water Body" or Central Aquifer (Figures 3-8, 3-9 and 3-10). Within this water body, groundwater is impounded to elevations of 250 to 300 feet in Koolau basalt by subsurface structures of apparent low permeability. The Schofield High-level Water Body is bounded by the Waialua Basal Water Body to the northwest and the Pearl Harbor Basal Water Body to the south. The Southern Groundwater Dam separates these two basal water bodies.

Termed "groundwater dams" by Dale and Takasaki (1976), the nature of the high-level water and impounding structures remains uncertain, though they have long been a subject of speculation and investigation. While the exact location and origin of the groundwater dam boundaries are not known, the existence of the dams has been inferred by steep potentiometric head differences across the two water bodies. The dam is suspected of being comprised of a system of dikes, a buried rift zone striking eastward of the Waianae caldera, or some other low-permeability structure.

As shown in Figure 3-12, in the Waianae rift zone, groundwater elevations reach about 1570 ft amsl (490 m), and about 960 ft amsl (300 m) in the Koolau rift zone. The Schofield High-level Water Body has a water elevation of about 275 ft (85 m). Between the coast and the inland geologic barriers water levels rarely exceed about 32 ft (10 m) in the basal aquifer. As a result of the large hydraulic gradient between the units, groundwater is believed to discharge from the Schofield High-level Water Body to the Pearl Harbor Basal Water Body.

The primary source of recharge to the Schofield High-level Water Body is believed to be from leakage of water stored within the dikes associated with the Koolau and Waianae rift zones. Groundwater generally flows from these rift zones in the east and west to the center of the Schofield Plateau where it converges in an area of stagnation or mixing in the western portion of the plateau. It then flows to the north and south over the northern and southern groundwater dams (HLA 1996).

Groundwater within the Schofield High-level Water Body, which discharges to the Pearl Harbor Basal Aquifer north of the Kunia Village, contains VOCs (primarily TCE), at concentrations above Federal MCLs, as outlined in the RI Report for the Schofield Barracks CERCLA site (HLA 1996). To date, there is no evidence that the Schofield High-level Water Body has negatively impacted the Pearl Harbor Basal Aquifer.

3.5.2.1.1.3 Caprock

In addition to the dike-related geologic barriers, the caprock located along the coast (Figures 3-1 and 3-7) acts to impede groundwater discharge near the coast, raising hydraulic heads in the layered basalt aquifers and creating semi-confining conditions. The caprock covers the basalt and inhibits the free discharge of groundwater to the ocean. Except beneath the caprock, basal aquifers are unconfined. Wells completed through the caprock into the basal aquifer below are often artesian (Figure 3-7). The caprock extends far-offshore above the submarine part of the aquifer (Souza and Voss 1987).

3.5.2.1.1.4 Waianae and Koolau Sections of the Pearl Harbor Basal Aquifer

Lavas of the Waianae and Koolau volcanoes comprise separate sections, or hydrologic units, of the Pearl Harbor Basal Aquifer, informally termed the Waianae aquifer and Koolau aquifer. The presence of these separate areas has been inferred by observed head drops across the erosional unconformity between the two lavas, and differing water level trend patterns in wells installed in the two lavas (Mink 1980). The differences have been attributed to the presence of a partial groundwater barrier along the contact between the Waianae and Koolau lavas. The barrier is believed to be comprised of a weathered zone and accumulations of alluvium, separating the lower, older Waianae lavas from the younger Koolau lavas (Stearns and Vaksvik 1935). Hydraulic continuity does exist between the Waianae and Koolau aquifers, however, and they are therefore included as part of the Pearl Harbor Basal Aquifer (Mink 1980).

It is important to note that the designation of the "Waianae aquifer" section of the Pearl Harbor Basal Aquifer used herein in this RI Report is an informal designation and is distinct and separate from the formally identified Waianae Aquifer, which is comprised of the dike-impounded water body of the Waianae Rift Zone and basal groundwater west of the rift zone. The Waianae Aquifer is completely separate from the Waianae section of the Pearl Harbor Basal Aquifer.

The contact between the Koolau and Waianae basalts (Figures 3-11, 3-12 and 3-13) is generally mapped as lying along the exposed surface contact of the two units. In Figure 3-4, this contact is shown approximately 4000 ft west of the Kunia Well. The effective separation lies further to the east, however, since the Waianae basalts dip from 5 to 10 degrees in this direction. At a dip of 10 degrees, the sea level contact (approximately the water table surface) is over 1 mile to the east of the surface contact. At a dip of 5 degrees, the sea level contact is even further to the east. This would indicate the Kunia Well is constructed in the Waianae aquifer. Additional discussion of this issue is presented below in Section 3.5.2.2.2.5.

Head drop across the unconformity is about 2 to 3 feet (Mink 1980) with heads in the Koolau being higher. Therefore, flow across the contact is always from the Koolau to the Waianae sections. The unconformity is believed a slight impediment to flow but not a barrier. To the west of the contact, the Waianae aquifer is bounded by the Waianae rift zone, to the north by the high-water boundary and to the south by the caprock. The aquifer is therefore a two to four mile wide strip approximately nine miles in length.

3.5.2.1.2 Recharge and Discharge of the Pearl Harbor Basal Aquifer

Natural groundwater recharge to the Pearl Harbor Basal Aquifer occurs mainly as a result of high rainfall and resulting infiltration in the upper elevation areas (Schofield plateau and Koolau mountain areas), discharge from the Schofield High-level Water Body, and discharge from the Koolau dike-impounded water body. Discharge from the Waianae High-level body is not believed significant due to the presence of a nearly absolute barrier along a line passing up the Makaiwa Gulch (Mink 1980), due to the low-permeability structures of the Waianae Rift zone, and due to the generally low amounts of rainfall which fall on the Waianae mountains and resulting low infiltration (Figure 3-3). It is estimated that approximately 425 mgd average rainfall occurs over the Pearl Harbor drainage basin, of which approximately 200 to 225 mgd, or roughly 50%, infiltrates to the basalt (Mink 1980).

Natural discharge occurs along a line of springs at the inland boundary of the caprock (Figure 3-7) near Pearl Harbor, and likely as leakage through the caprock to Pearl Harbor (Voss and Wood 1993). Some leakage from the Koolau to the Waianae basalts occurs across the erosional unconformity between the two lavas.

Recharge of the Waianae aquifer section of the Pearl Harbor aquifer is primarily via infiltration of direct rainfall, discharge from the Schofield High-level Water Body, and leakage from the Koolau basalts through the erosional unconformity. Natural discharge occurs as leakage to the caprock, and a small component of flow across the Makaiwa barrier toward Kahe (Mink 1980). It is important to note that discharge is not believed to occur from the Waianae to the Koolau basalts. Flow across the unconformity is from the Koolau to the Waianae lavas as evidenced by the higher potentiometric heads in the Koolau across the contact.

In addition to natural discharge, pumping centers throughout southern Oahu comprise an important discharge component of basal groundwater. Pumping from the Pearl Harbor aquifer began in the early 1880s related to sugar cane development, and rates of withdrawal increased continuously through about 1980 with resultant reductions in head and upward/landward movement of the transition zone between fresh and salt water. Most wells for public and irrigation supply are located near the coast (Figure 3-14). Pre-development heads in the aquifer ranged from about 32 ft (10 m) near the coast to 38 ft (12 m) near the upstream boundary. The pre-development fresh water lens was about 1300 to 1600 ft (400 to 500 m) thick (Mink 1980). In 1990, fresh water heads in the aquifer ranged from about 16 to 22 ft amsl (5 to 7 m), and the fresh water lens had been reduced to only about 650 to 1000 ft (200 to 300 m) thick (Voss and Souza 1993). Some

wells were abandoned due to increased salinity. Recently, with the end of sugar cane production on Oahu, irrigation pumping has been reduced.

Directions of groundwater flow in the Pearl Harbor Basal Aquifer are depicted in Figures 3-12 and 3-13. Flow in the Koolau lavas occurs generally in a southerly direction from the Koolau mountains towards Pearl Harbor. Depending on location, flow can range from southeasterly to southwesterly. Flow in the Waianae, however, is believed to be southwesterly from the erosional unconformity, which comprises the most significant source of recharge to the aquifer. Prior to the performance of this RI, the aquifer beneath the Kunia Village Area had not been defined. This evaluation is presented below in Section 3.5.2.2.2.5.

3.5.2.1.3 Hydraulic Properties of the Pearl Harbor Basal Aquifer

**Hydraulic Conductivity.** Numerous pumping tests have been conducted in the Pearl Harbor aquifer to derive estimates of horizontal hydraulic conductivity. An average hydraulic conductivity of 1561 ft/day and storage coefficient of 0.034 were reported by Mink (1980) based on an analysis of recovery data from six wells monitored during a shutdown of irrigation pumping in 1958. The range of hydraulic conductivities from the tests was on the order of 1000 to 2500 ft/day. Wentworth (1938) calculated an hydraulic conductivity of approximately 1800 to 3500 ft/day based on a controlled pumping test at the Waialae Pumping Shaft. Williams and Soroos (1973) summarized data for all major pumping tests done after Wentworth's effort and reported similar values. The average value for ten of the best tests was 1841 ft/day. On the basis of these data, hydraulic conductivity of the Pearl Harbor basal aquifer appears to range from about 1000 to 3500 ft/day with an average value in the range of about 1500 to 2000 ft/day. This range of values is consistent with the results of a recent hydrogeologic study of the Central Oahu aquifer conducted by the USGS (Oki 1998).

While the horizontal conductivity is reasonably well-understood, vertical permeability has never been directly measured. Rough estimates of anisotropy indicate that the vertical permeability may be on the order of one to three orders of magnitude less than the horizontal (Souza and Voss 1987). Permeability in both directions is so great however and so subject to local deviations that any difference between them may be difficult to asses (Visher and Mink 1964).

**Effective Porosity.** The effective porosity of the thinly layered basalts is poorly known. Mink (1980) reports that little attention has been focused on obtaining a quantitative estimate of the parameter due to the extreme heterogeneity of basaltic aquifers, but that an effective porosity of 10% is commonly assumed. Peterson and Segal (1974) report estimates of from less than 5% in dense flows to 50% in clinker zones. Voss and Wood (1993) report that effective porosity is less than 10% and assumed a value of 4% in a regional groundwater flow model of freshwater/saltwater interaction. Orr and Lau (1987) report values between 5 to 10%.

**Gradient.** Horizontal gradients for the Koolau and Waianae aquifers vary from about 1 to 1.5 ft/mile as reported in Mink (1980). No information is available on the magnitude of

any vertical gradients. Vertical gradients would be expected to be generally downward in the recharge areas and upward in the discharge areas near the coast. The Kunia Village Area, because of its inland location, is within a recharge area.

**Groundwater Velocity.** The groundwater velocity is a function of hydraulic conductivity, hydraulic gradient and porosity. Considering the ranges of possible values presented above for these parameters and assuming most likely average values for the Pearl Harbor Basal Aquifer of about 1500 ft/day hydraulic conductivity, 1 ft per mile gradient and porosity of 0.075, the representative velocity is about 1500 ft/yr.

3.5.2.1.4 Regional Groundwater Supply and Monitoring Wells

3.5.2.1.4.1 Wells Sampled during the RI

Sampling of regional wells was included in the RI field effort in order to provide regional groundwater chemical and water level data. These included the "Navy" well (Del Monte Well #3, State Well No. 2803-05) located 1 mile north and upgradient of the Kunia Village Area, the Hawaii Country Club Well (State Well No. 2603-01) located approximately 1.5 miles south of the Kunia Village Area, and basal monitoring well STMW005 at the US Air Force's Waikakalaua Fuel Storage Annex (FSA) located approximately 2 miles east of the Kunia Village Area. In addition, Del Monte Well #4 (State Well No. 2803-07) and five other groundwater supply wells (2803-01 to -04, and -06) owned by the US Navy are located in the Schofield High-level Water Body near Del Monte Well #3 (State Well No. 2803-05). Collectively, these groundwater supply and monitoring wells comprise all wells within a 2 mile radius of the Kunia Village Area.

The locations of these wells, as well as other wells in the area, are shown in Figure 3-14. Relevant data for these wells from the State Department of Health's well database (HDOH 1996) are listed in Table 3-6.

3.5.2.1.4.2 Navy Well (Del Monte Well #3)

Del Monte Well #3 (State Well No. 2803-05), the "Navy Well", is located in pineapple field 6 approximately 1 mile north of Kunia Village. In April 1980, the well replaced the Kunia Well as a source of potable water and continues to provide drinking water for Kunia Village. The water source is treated by a Packed Tower Aeration Facility ("Stripping Tower") located in field 8 next to the domestic reservoir. The Stripping Tower, installed in 1989 and approved by the HDOH in 1991, is effective in removing VOCs such as TCE from the drinking water prior to human consumption. In September 1997, DMFP entered into an agreement with the US Army whereby the Army agreed to provide DMFP with resources for the removal of TCE from the drinking water supply for Kunia Village.

The well was drilled in 1959 to a total depth of 1020 ft, and completed with a 20 in diameter well casing. Ground surface elevation at the well is approximately 857 ft amsl. Perforated casing extends from 661 to 887 ft depth. The well is completed within the Schofield High-level Water Body based on a reported water level in the well of

approximately 581 ft bgs (elevation of approximately 275 ft amsl) (HDOH 1996). This elevation is consistent with typical groundwater elevations in the Schofield High-level Water Body. A copy of the driller's log of this well is included in Appendix B.

Five wells owned by the US Navy (2803-01 thru -04, and -06) are located within a 500 ft radius of the Navy Well (Table 3-6 and Figure 3-14). These wells are located within the Schofield High-level Water Body.

3.5.2.1.4.3 Del Monte Well #4

Del Monte Well #4 (State Well No. 2803-07) is located within 300 ft west of Del Monte Well #3. The well was drilled in 1979 to a total depth of 990 ft, and completed with a 16-in diameter casing. Solid casing extends to a depth of 830 ft. Perforated casing extends to the final well depth of 990 ft. A copy of the driller's log of this well is included in Appendix B. This well is not sampled as part of the RI, however, HDOH routinely collects water samples from the well for monitoring purposes.

A water level of approximately 200 ft amsl is reported in the State well database (HDOH 1996), placing the well in the High-level Water Body, or possibly within an intermediate zone between the High-level Body and the basal aquifer.

The well has been used since 1991, after approval from the HDOH, as an alternate source of drinking water to the Navy Well.

3.5.2.1.4.4 Hawaii Country Club Well

The Hawaii Country Club (HCC) Well (State Well No. 2603-01), located approximately 1.5 miles south of the Kunia Village, is the nearest potentially downgradient well to the Kunia Village Area. The well was drilled in 1961 to a total depth of 1047 ft, and was completed with a 12-in diameter casing. Perforated casing was installed from 726 to 777 ft below ground surface. An initial water level elevation of 23.6 ft amsl is reported in the State's well database (HDOH 1996).

As part of this RI, the well was sampled in order to monitor for the presence and concentration of COPCs at a location potentially downgradient of the Kunia Village Area. The water level elevation at this well was measured on February 18, 1998 at 21.89 ft amsl. This is following the installation and surveying of a new sounding tube for water level instrument access. Additional discussion of water levels is provided below in Section 3.5.2.2.2.2.

The HCC well is used both for drinking water in the Club House and irrigation purposes. Prior to human consumption, the water is treated with a carbon adsorption unit. The performance of the unit is monitored by HDOH. Drinking water for the golf course is supplied by DMFP from the potable water system serving Kunia Village. In addition to RI sampling activities, the well is routinely sampled by the HDOH for water quality parameters including EDB, DBCP and other VOCs.

A copy of the driller's log for this well is included in Appendix B.

3.5.2.1.4.5 Waikakalaua Fuel Storage Annex (FSA)

The Waiakakalaua Fuel Storage Annex (FSA) is located approximately 1.5 miles east of the Kunia Village Area near the current pineapple field 2. The Waiakakalaua FSA, along with the Kipapa FSA and Valve Pit No. 17, were used for aircraft re-fueling operations at Wheeler Military Airfield until the 1970s. The facilities are owned by the U.S. Air Force. Related to closure, the Air Force is currently conducting environmental investigations using CERCLA guidance at these facilities.

Five basal monitoring wells are installed at the facility as shown in Figure 2-17. In addition to these, there are two shallow wells, MW-6 and MW-7 (2702-01 and -02, respectively), constructed to 155 ft bgs. Available construction information for these wells is summarized in Table 3-6.

One of the five basal wells, well ST12MW005 (MW05, or 2702-05), was selected by Golder/DMFP for sampling during the RI. The purpose of the RI sampling activities is to provide chemical data representative of basal groundwater in areas unaffected by any potential releases in the vicinity of the Kunia Village Area.

The well is located along the southwestern perimeter of the FSA site (Figure 2-17). Its location is believed hydraulically downgradient or cross-gradient from the USTs located on the site (The Environmental Company 1997). The well was drilled to a total depth of 730 ft bgs and is completed with a 4-in diameter Sch 80 PVC casing and stainless steel screen to 707 ft bgs. The screened interval is from 681 to 707 ft bgs. Based on the well's location, the well is believed to be constructed in the Koolau portion of the Pearl Harbor Basal Aquifer.

Given that the well is neither upgradient or downgradient of the Kunia Village Area, EPA provided approval of DMFP's request to remove this well from the sampling schedule after the initial round of sampling.

3.5.2.1.4.6 Other Regional Wells

Other regional water supply wells include possible downgradient wells located south of the Kunia Village Area, such as the Honouliuli I and II wells (State Well Nos. 2303-01 thru -07), and Kunia I and II wells (State Well Nos. 2302-01 thru -04 and 2402-01 thru -03, respectively). Each of these wells is owned and operated by the Honolulu Board of Water Supply (BWS). Honouliuli I wells are no longer used by the BWS, while the Honouliuli II wells pump at a combined rate of 5 to 7 million gallons per day. The locations of these wells are shown in Figure 3-14, and construction details are summarized in Table 3-6. These wells are located at least 4 miles south of the Kunia Village Area. In early 1998, EPA provided approval of DMFP's request to include one of the Honouliuli II wells (2303-03) in the regional well sampling program.

Honouliuli I/II wells and the Kunia I/II wells are constructed in the Waianae and Koolau aquifers, respectively, based on their locations with respect to the Koolau/Waianae unconformity. These aquifer assignments are also made in the HDOH's well database. A well construction log and driller's log of Honouliuli I wells #1 and #2 (2303-01 and 2303-02) are included in Appendix B. An interpretation of these logs and additional discussion of aquifer identifications for these wells is included below in Section 3.5.2.2.2.5.

The US Navy's Barber's Point Shaft (State Well No. 2103-03) is located approximately 2.4 miles south of the Honouliuli wells (Figure 3-14 and Table 3-6). The well is a 72 in diameter tunnel constructed in 1943 to a total depth of 204 ft bgs. Ground surface is approximately 200 ft amsl at the well location. The well is used to supply drinking water to the Barber's Point Naval Air Station. A head of 14.1 ft amsl is reported in HDOH (1996) for the well. The well is assigned to the Waianae aquifer section of the Pearl Harbor aquifer in the HDOH database (HDOH 1996).

The Makakilo well (State Well No. 2004-04) is a Honolulu BWS well located approximately 3.5 miles southwest of the Honouliuli wells. The well was installed in 1981 to a total depth of 268 ft bgs. Ground surface elevation at the well is about 141 ft amsl. The well is a 14-in diameter municipal supply well. A head of 14.9 ft amsl is reported in HDOH (1996). The well is assigned to the Waianae aquifer section of the Pearl Harbor aquifer in the HDOH database (HDOH 1996). The well has been inactive due to high chloride but was recently equipped with a new pump and may be returned to service (Personal Communication, Mr. Kevin Gooding, Honolulu BWS).

3.5.2.2 Hydrogeology of the Kunia Village Area

This section describes the site-specific hydrogeologic conditions of the Kunia Village Area. It is based primarily upon the RI drilling, well installation well testing and other related field data collection activities. All hydrogeologic data collected during the RI is presented in this section. Groundwater chemistry data are presented in Chapter 4.

Data appendices relevant to this section of the RI report include the following:

- Appendix B Borehole and Well Construction Logs
- Appendix C Results of Laboratory Physical Testing
- Appendix E Well Testing Data and Analysis
- Appendix F Basal Well Geophysical Testing and Deviation Survey Results

3.5.2.2.1 Perched Aquifer

3.5.2.2.1.1 Stratigraphy

Hydrogeologic cross-sections through the Kunia Village area are shown in Figures 3-15, -16 and -17.

Perched aquifer materials consist generally of fine-grained silty clays and clays (CH and CL) derived either from complete to nearly-complete weathering and breakdown of the original unweathered basaltic lavas or from near-surface alluvium/colluvium. These materials are separated into the following two types:

- Surficial soils and subsoils which typically extend to a depth of 10 to 15 ft bgs or less, and
- an underlying saprolite which extends to a depth of approximately 80 to 100 ft bgs.

Surficial materials are comprised of brown and reddish brown, soft to stiff silty clays and clays. Organic matter (roots) is prevalent in the upper few feet. Surficial soils and subsoils are believed to be alluvial or colluvial deposits associated with the Waianae Range to the west (especially near the surface), and/or derived from in situ weathering of basaltic lava.

An area of fill soil, evidenced by black plastic observed at a depth of approximately 10 ft, is present in the vicinity of MW-3 and P-7. This fill material replaced impacted soils removed as part of previous remedial activities conducted in the early 1980s.

The saprolite consists of brown and reddish brown, stiff to very stiff, vesicular, friable, silty clays and clays. Organic matter is low to absent. Relict minerals are evident, with mineral infilling of vesicles. Boulders of moderately weathered basalt occur locally. The saprolite was formed by nearly complete in situ weathering of intact basaltic lava.

The surficial soil, subsoils and saprolite are very similar in appearance and properties and are somewhat difficult to differentiate in Strataprobe sampling. Both the surficial materials and saprolite contain a high percentage of fines with generally less than 10% sand and gravel content. The contact between the two zones is somewhat indistinct and variable, but is generally characterized by an increase in density and the prevalence of relict minerals and vesicles which occur in the saprolite.

The base of the saprolite occurs at variable depths, but generally within elevation 740 to 760 ft amsl. The contact is clearly evident by a color change from the reddish brown saprolite to a greenish gray moderately weathered basalt, as well as increased resistance to drilling (in auger drilling). Auger drilling encountered refusal after penetrating several feet into the weathered basalt and density became hard upon entry into the basalt. The elevation of the base of the saprolite is uncertain in the vicinity of MW6 (but is at least lower than 730 ft amsl) as it was not encountered at this location (Figure 3-17). This may indicate the base of saprolite dips to the east, consistent with the general topographic relief.

Observations during Basal Well drilling, which penetrated beyond the saprolite/weathered basalt contact, indicate weathered basalt extends some 100 additional feet (to a depth of approximately 200 ft at the Basal Well location) before relatively unweathered basalt is encountered. Drilling resistance was low and cuttings

indicated evidence of weathering throughout the upper 200 ft before unweathered basalt was encountered.

The occurrence of the weathered basalt beneath the saprolite has not previously been reported for the Kunia Village Area, but is not unexpected. Weathering of the surface of the basaltic rock is reported in Visher and Mink (1964) to commonly extend to depths of 50 to 75 ft below the rock surface. The weathered rock is simply a transitional material between the completely weathered rock (saprolite) and fresh lava. As such, the hydraulic properties of the material would be expected to be intermediate between the low permeability saprolites and the high permeability fresh basalt. Hydrologic data discussed below indicate the material is unsaturated, however, at the Kunia Village Area. Since the evidence indicates the material is unsaturated, the zone does not represent a separate hydrologic unit, but may simply be considered part of the unsaturated basalt sequence which extends from the base of the saprolite to the water table.

Therefore, a generalized stratigraphic column of the uppermost materials at the Kunia Village Area includes some 10 to 15 ft of surficial soils and subsoils overlying saprolite. The saprolite extends to a depth of 80 to 100 ft before encountering a weathered basalt surface. Weathered basalt continues to a depth of approximately 100 additional feet before unweathered basalt is encountered at about 200 ft bgs. Hydrologic data included below confirm that the perched aquifer is confined to the area above the weathered basalt (within the saprolite).

3.5.2.2.1.2 Depth to Groundwater and Extent of Perched Aquifer

Water levels in piezometers and monitoring wells are summarized in Tables 3-7 and 3-8, respectively.

**Depth to Water.** The water table surface of the perched aquifer is encountered at depths between about 0 ft (during rainy periods) near the edge of the pit to over 40 ft bgs, depending on location and season. This corresponds to elevations of about 820 ft to 780 ft amsl. Levels are generally nearest the ground surface at the pit edge (i.e., where the pit was excavated into the water table) and deepest away from the pit (both to the north and south), such as in the upper elevation areas near the Kunia Well and to the NE of the pit near P-8. The elevation of the perched water table drops considerably to the north of the pit area, in the vicinity of MW-4 and P-8. No water was observed at MW-4 during drilling, or after allowing the open borehole (drilled completely through the saprolite into weathered basalt) to remain open for 24 hours on at least two separate occasions. There were no indications during drilling that saturated conditions had been encountered. This indicates the extent of the perched aquifer is limited to the area south of MW-4, or south of a line approximately parallel to the ephemeral gulch.

**Seasonal Fluctuations.** Heads in the perched aquifer are expected to vary seasonally on the basis of rainfall. Between April 1997 and July 1998, groundwater heads generally declined from about 10 to 20 ft in the perched aquifer at most locations due to low rainfall (Table 3-8). Levels at MW-6, however, declined by about 22 ft while levels at MW-2 declined only 6 ft. At the beginning of this time period, the elevation of water in

the pit, which is believed representative of heads in the shallow portion of the perched aquifer, was unusually high on a historical basis. The pit has since dried out considerably, which is reflected in the lowered heads throughout the perched aquifer.

**Thickness of Saturated Material in the Perched Aquifer.** Evidence obtained while drilling MW-2 and MW-3 (discussed below) indicates that the weathered basalts underlying the saprolite are unsaturated. Therefore the saturated interval is from the water table surface to the base of the saprolite. Water level data indicate that the thickness of the perched aquifer is greatest (about 80 ft thick) in the upper elevation areas near the new Basal Well and piezometer P-1 (southern pit area) and that it then thins progressively to the north-northeast to 0 ft in the vicinity of the ephemeral gulch, as evidenced by the lack of water observed at MW-4 and the low level at P-8.

3.5.2.2.1.3 Groundwater Flow

Contour maps of potentiometric surface elevations for the perched aquifer are shown in Figures 3-18 and 3-19 for the upper perched aquifer and lower perched aquifer, respectively. Figures 3-16 and 3-17 depict groundwater elevations in a cross-sectional view. Data used to generate the figures were collected in October 1997.

**Horizontal Flow.** As seen in the figures, the horizontal direction of groundwater flow in both the upper and lower portions of the aquifer reflects the general topographic relief of the immediate Kunia Village Area with flow towards the north and northeast. Flow is from the upper elevation portions near the Basal Well, down through the pit area and towards the ephemeral gulch. Near the ephemeral gulch, there may be a component of flow towards Kunia Road (to the east). The gradient is similar in both portions of the aquifer at approximately .15 ft/ft. As indicated above, the perched aquifer is believed to be limited to the area south of the gulch.

**Vertical.** Strong downward gradients are noted in the perched aquifer, with head differences of about 20 to 30 ft between the upper and lower portions of the aquifer. This results in downward vertical gradients on the order of about 0.5 to 1. At well pair MW-3/-3s, the gradient is approximately 0.8. At wells MW-1 and P-2, the gradient is about 0.4. At MW-2 and P-6, the gradient is about 1, however, MW-2 is screened primarily in the weathered basalt, and so this gradient is not considered representative of the perched aquifer.

**Drilling Observations (MW-2 and MW-3).** Water level observations made while drilling wells MW-2 and MW-3 are key to characterizing the perched aquifer. These included the following:

- Well MW-3 was first constructed with a screened interval that extended partially into the weathered basalt. Upon completion, the water level dropped progressively and the well eventually went dry. As a result, the well was drilled out and a new well constructed in the same borehole, with a screen entirely in the saprolite (see Figure 3-16). The final well indicates a groundwater head in the aquifer some 20 ft above the base of saprolite.

- Well MW-2 is constructed with the screen mostly in the weathered basalt, and partly in the saprolite. While the well has not gone dry, the head is considerably lower than other perched aquifer monitoring wells, for instance, approximately 20 ft lower than at MW-3, suggesting unsaturated conditions in the weathered basalt.

These observations strongly suggest the weathered basalt underlying the saprolite is unsaturated, and that the base of the saprolite does indeed constitute the bottom of the perched aquifer. In addition, no water was observed at MW-4 during drilling and after allowing the open borehole to remain open, indicating the extent of the perched aquifer is limited to south of the ephemeral gulch. Well MW-4 penetrated into the weathered basalt.

3.5.2.2.1.4 Physical Properties

Results of slug testing performed on monitoring wells and selected piezometers, and the results of laboratory permeability tests conducted on undisturbed samples of saprolite are summarized in Table 3-9. Results of physical properties testing conducted on surficial materials and saprolite are summarized in Table 3-10. Appendix E includes a complete discussion of slug testing procedures and test analyses. All laboratory testing results are presented in Appendix C.

**Hydraulic Properties.** Transmissivity was derived from the slug test analyses and hydraulic conductivity was computed by assuming that the contributing flow was evenly distributed over the saturated portion of the screened interval. The 9 test intervals in the saprolite perched aquifer show a range of less than 2 orders of magnitude, 3.24E-06 cm/s to 2.11E-04 cm/s. In intervals with results derived from both injection and withdrawals test types, there is good consistency with the difference less than one half an order of magnitude. This range of values equates to conductivities in the range of about 0.01 to 1 ft/day.

Laboratory results, which measure vertical conductivities of discrete samples of undisturbed material, range from 3.1E-07 cm/s to 1.4E-05 cm/s. This is a range approximately one order of magnitude smaller than that measured in the slug test results, or about 0.001 to 0.1 ft/day. This is not surprising considering that vertical permeabilities are expected to be generally smaller than horizontal permeabilities measured in slug tests, and slug tests sample a larger volume of material than a lab test and may therefore reflect some contribution from discrete higher conductivity flow features such as macropores, or fractures.

Hydraulic conductivities of the perched aquifer were reported previously in Mink (1980) based on pumping tests performed in uncased boreholes completed in the saprolite at the Kunia Village Area. The results varied but the maximum hydraulic conductivity was estimated at 1 ft/day. Mink (1982) reported a hydraulic conductivity of approximately 0.1 ft/day based on pumping tests performed in completed wells.

On the basis of these results, the hydraulic conductivity of the perched aquifer is quite low. Horizontal conductivity is probably on the order of 0.01 to 1 ft/day, and vertical conductivity is about one order of magnitude less.

**Physical Properties.** Laboratory measured physical properties are summarized in Table 3-10. Key elements are as follows:

- Total porosity of the surficial materials is quite high, and ranges from about .5 to .6.
- Soils are comprised of silty clays and clays (CH and CL) with a fines content of 90% or more.
- The specific gravity of the soil solids is about 2.8 to 3.0 which is typical of clayey and silty soils.
- Percent organic carbon ranges from less than 0.01% to about .1%.

3.5.2.2.1.5 Recharge and Discharge of the Perched Aquifer

Recharge of the perched aquifer is via direct rainfall infiltration through the surficial soils and subsoils. Recharge is believed to be enhanced, perhaps significantly so during periods of heavy rainfall, by the presence and topography of the pit area, which acts to collect and concentrate rainfall runoff where it then may infiltrate to the subsurface.

The low permeability of the saprolites leads to a localized perched condition atop the basalt. Discharge then occurs primarily via vertical leakage to the more permeable weathered basalts underlying the saprolite (and eventually to the basal aquifer) as evidenced by the strong vertical gradient. Some horizontal flow component is present to the north to northeast, but as evidenced by the lack of saturated conditions north of the gulch, vertical leakage is so dominant that the perched aquifer eventually thins out and is absent north of the gulch. The thickness and extent of the perched aquifer may be largely a result of, or at least influenced by, local drainage patterns and the concentration of runoff in the pit and ephemeral gulch area. This runoff locally exceeds the infiltration capacity of the saprolite resulting in the creation of a saturated mound condition atop the basalt.

No seeps or evidence of surface discharge were observed during the RI. In addition, the perched aquifer does not discharge to the ephemeral gulch as evidenced by low hydraulic heads in the vicinity of the gulch.

3.5.2.2.1.6 Assessment of Pre-RI Perched Aquifer Wells

Three perched aquifer monitoring wells were installed at Kunia Village in December 1980. The locations of these wells are shown on Figure 2-1. Two of the wells are located in the former storage and mixing areas (Well Nos. 6 and 9) and one is located in the spill area (Well No. 3). The wells were located in the areas believed to contain the highest concentrations of chemicals and were used as pumping wells in remedial efforts aimed

at recovering impacted perched aquifer groundwater. Pumping began in the wells during 1981.

Well Nos. 3, 6 and 9 are completed to depths of 106, 82 and 79 ft bgs, respectively. Each well consists of 15-in diameter US Steel copper steel casing completed within a 22-in diameter borehole. The lower 50 ft of casing in each well is perforated with 10 to 18-in long slots approximately 3/8-in wide (ICF 1995a). The slots are spaced vertically 4 to 12 inches. The annular space of each well was backfilled with 1/4- to 3/4-in gravel from ground surface to the total depth. No surface seal or grout was used. Each of the wells is equipped with a pump rated at 10 gpm. No lithologic logs are available for these wells.

During prior remedial activities, soils around each of the three wells were excavated. As a result, portions of Well Nos. 6 and 9 were cut. Well 6 may have been damaged during soil excavation as it apparently silted up soon thereafter and sustainable pumping was no longer possible. After 1983, sustainable pumping and sampling was conducted only from Well No. 9. Wells No. 9 and No. 3 are currently being pumped to extract water for the Phytoremediation Treatability Study.

Since the wells screen essentially the entire perched aquifer, water levels are not comparable to those obtained from the RI wells, which screen discrete zones, due to the presence of strong vertical gradients.

3.5.2.2.2 Basal Aquifer

3.5.2.2.2.1 Stratigraphy

**Kunia Well Log.** A copy of the driller's log for the Kunia Well is included in Appendix B. Interpretation of the log for the Kunia Well indicates that in the upper 200 to 250 ft from ground surface, saprolite and weathered basalt were encountered. Unaltered lava extends below this depth to 304 ft bgs. From 304 to 331 ft, a "sand and silty lava" is noted. This is interpreted to represent a weathered zone in the lava sequence. Below 331 ft to the bottom of the boring at 976 ft, "hard and soft lava" is indicated, believed to represent unaltered lava.

**Basal Well Log.** Logging of the Basal Well was conducted by visual examination of drill cuttings ejected from the borehole. Cuttings were collected at intervals of approximately once per five feet. A stratigraphic log of the Basal Well based on examination of the cuttings is shown in Figure 3-20. Stratigraphy at the Basal Well is described as follows:

- The base of the saprolite (and top of basalt) was encountered at a depth of approximately 115 ft below ground surface. This contact, which is consistent with that observed during auger drilling, was observed primarily by a color change from reddish brown to an olive color.
- Beneath the saprolite, a transitional zone was observed. This transitional zone, equivalent to the zone of weathered basalt encountered during auger drilling, extends from 115 ft to about 200 ft below ground surface.

- Unaltered, competent basalt was observed at about 200 ft depth and extended to the total depth of the borehole at 993.5 ft depth. This is consistent with the log of the Kunia Well which indicated unaltered lava beginning at about 200 to 250 ft bgs.
- No material other than unaltered lava was noted during drilling, such as saprolite, or cinders. Nor were any zones of lost circulation or hole instability encountered. A possible saprolite zone was noted at 885 depth but this was uncertain, and if present, was thin.
- In general, the material to a depth of about 520 ft was primarily greenish black in color. Lava below this depth was primarily reddish brown. The drilling rate generally was faster in the reddish brown basalt. Color changes such as these, however, are not believed distinctive of any particular geologic formation, such as Waianae or Koolau lavas.

**Water Notes while Drilling.** Water was consistently observed in the borehole in the upper 200 ft prior to the sealing off of this upper section with steel casing. Refer to Table 3-11 for a summary of water notes made while drilling the Basal Well. As seen in the table, a water level of about 36 to 38 ft bgs was consistently observed in the borehole while drilling down to 202.8 ft, the depth to which the steel surface casing was installed. No water was detected after the casing was installed and grouted. This could suggest that the bottom of the saturated zone extends to a depth of approximately 200 ft, which is about 100 ft deeper than that suggested by auger drilling. However, caution is warranted when interpreting water level data taken in open boreholes.

Since the borehole was open over the entire 200 ft thickness, water present in the borehole can originate from anywhere in the open interval, even though the entire interval may not be saturated. The observation of water in the borehole during drilling is therefore not considered definitive in determining that the zone of saturation extends to a depth of 200 ft. Water level information collected during auger drilling, such as at well MW-2 and MW-3 in particular, where data are from completed monitoring wells installed across distinct isolated zones, is considered more reliable in determining the base of the saturated zone. Water observed in the Basal Well borehole is believed to be derived from the perched aquifer located within the upper 100 ft of the borehole. Water was observed in the borehole because it flowed in from this zone and not because the saturated zone extends to 200 ft.

No other water was detected coming into the borehole except for a zone from approximately 658 to 705 ft. This observance was made by the driller based on wetness detected in foam circulation. Beneath 705 ft to the water table at a depth of about 826 ft bgs, no water was detected while drilling. The observation of wetness in the zone from 658 to 705 ft is considered tentative due to the qualitative and inconclusive nature of the observation. It is important to note however that this observation is somewhat consistent with observations made in the Kunia Well during a video log, discussed below, where water is observed entering the Kunia Well screen at a depth of about 674 ft bgs. It is considered possible that a perched groundwater layer is present in the vicinity

of 650 to 700 ft bgs. The presence of this perched layer may be the reason the Kunia Well screen extends approximately 200 ft above the surface of the water table.

**Natural Gamma.** A natural gamma log was conducted of the Kunia Well. This technique, can be used to differentiate between geologic units or rock types based on differences in the natural gamma-ray emitting characteristics of the material. Differences in the uranium, thorium and potassium content result in changes in gamma emission. Therefore, it is theoretically possible to identify the contact between the Koolau and Waianae basalts, or the presence of saprolite, using this technique. Koolau and Waianae basalts, because they are derived from different volcanic sources, may have different gamma emission signatures. Saprolite may also be differentiated since the weathering process may alter the mineralogic content of the parent material. Saprolite, or a zone of weathering at depth in the Kunia Well, could be indicative of the former eroded surface of the Waianae basalts. The results of the natural gamma log are shown in Appendix F.

The interpretation of the natural gamma log can be complicated in the Kunia Well by the relatively large size of the borehole, and the presence of the steel casing. The size of the borehole means the tool may hang far from the rock, and may at times, drag on the casing wall, making the distance to the rock variable as the tool is lowered in the well. These factors could lead to anomalies and complicate the interpretation of results.

A deviation log of the Kunia Well, however, indicates that these may not be significant concerns for the Kunia Well. The log, shown in Appendix F, indicates that well is relatively straight. The total deviation between the top and bottom of the well is only about 2.75 feet. Most importantly, the well is free of sharp bends or changes in slope. It essentially slopes off in the same direction all the way down. This means the tool will drag against the same side of the borehole all the way down and will not change sides as it is lowered into the well. The tool therefore is always a constant distance from the rock. Examination of the natural gamma log results are believed useful therefore in evaluating borehole stratigraphy. Observations are as follows:

- The upper 208 feet display a relatively high natural gamma count. At 208 feet a sharp contrast and reduction in gamma count are noted. It is speculated that this depth represents the contact between the weathered and unweathered basalt, consistent with that observed in the basal well drilling. The gamma response in the upper 208 feet would therefore be indicative of a weathered basalt and/or saprolite material.
- At depth 528 ft and extending to about 584 ft, a similar response is noted, indicating a potential zone of weathered basalt or saprolite. Beneath this point to about 780 feet, unweathered basalt is indicated. Apart from these features and the water table surface at 822 ft, no significant features are noted. No indications of weathering were observed in the zone from 304-331 ft bgs where a possible weathered zone was noted in the driller's log.

**Stratigraphy Interpretation.** These results combined with the Basal Well drill cuttings are interpreted to generate the following conceptual view of basalt stratigraphy at the Kunia Village Area:

- The upper 200 ft consists of saprolite and weathered basalt. With the exception of the possible weathered zones discussed below, generally unweathered basalt extends below this depth to the base of the Basal Well.
- No direct evidence was obtained from the Basal Well drill cuttings of a weathered zone which may represent the Waianae/Koolau unconformity. However, there are other indications which are believed to provide reasonable evidence that the unconformity is present. A possible weathered zone in the Kunia Well is noted in the natural gamma log from about 528 to 584 ft feet depth. The Kunia Well driller's log suggests a weathered zone may occur from 304 to 331 ft bgs. Indications of possible perched water, which could represent a weathered zone, include the observation of increased water in Basal Well drill cuttings from 658 to 705 ft bgs, and the observation of water entering the Kunia Well at 674 ft (discussed below in Section 3.5.2.2.2.4). The Kunia Well screen placement also suggests water was encountered at approximately this depth during Kunia Well drilling. These zones are speculated to represent potential locations of the contact between the Koolau and Waianae basalts, as discussed further below in Section 3.5.2.2.2.5.

3.5.2.2.2.2 Groundwater Levels and Flow Direction

Water levels measured in basal wells are listed in Table 3-12. As seen in the table, the depth to water in the basal aquifer at the Kunia Village Area is approximately 825 to 830 ft bgs, or about elevation 22 to 23 ft amsl.

The water table elevation at the Basal Well was measured about 0.01 to 0.02 ft higher than the elevation in the Kunia Well on the two occasions when water levels were measured. Given the expected gradient between the two wells of about 1 ft per mile, the Basal Well should exhibit a groundwater head approximately 0.03 ft lower than the Kunia Well. However, the expected accuracy in the water level measurements, which is believed to be on the order of about 0.1 feet over the 820 ft distance to the water table surface, is not believed sufficient to distinguish this small expected head difference. The flow direction is believed to range from approximately southerly to southwesterly, as indicated below in Section 3.5.2.2.2.5.

The elevation of water in the Hawaii Country Club well was measured at approximately 22 ft. This measurement was made following the installation and surveying of a new sounding tube to allow access to the well for water level measurement purposes. The water level measurement was made while the pump was inoperative.

Elsewhere in south-central Oahu several heads were measured within a month of those discussed above. The BWS monitor well named Kunia and numbered as BWS T-41 (State No. 2201-10) had a head of 19.18 feet on February 10, 1998 (data from C. Lao, Hydrologist at BWS). This monitoring well is completed within the Koolau aquifer based on its location. A well called the Honouliuli monitoring well (2303-07), which is completed within the Waianae aquifer based on its location, had a head of 15.65 ft on January 18, 1998 (data from Tom Nance, Water Resources Engineering). The data from T-41 and the Honouliuli monitoring well may be correlated with data from the Kunia

Well, Basal Well and HCC well to determine which aquifer these latter three wells are completed within.

Table 3-13 lists the wells, their heads, differences in head, and the calculated groundwater gradient in ft/mile. The Kunia Well serves for itself and the Basal Well since the two wells are just 156 ft apart. The distance between the well pairs is listed in Table 3-13.

In both the Waianae and Koolau aquifers in southern Oahu, the average groundwater gradient is believed to be approximately 1 to 1.5 ft/mile (Mink 1980). As indicated in Table 3-13, the gradient between the Kunia Well and well T-41, which is known to be in the Koolau aquifer, is 0.62 ft/mi, nearly 1 ft/mi less than the normal Koolau gradient. On the other hand, the gradient between the Kunia Well and the Honouliuli monitoring well is 1.39 ft/mi. This indicates the Kunia Well is completed within the Waianae aquifer section of the Pearl Harbor Basal aquifer.

For the HCC well, while the view is not as definitive as with the Kunia Well, the data are believed to indicate the well is also constructed in the Waianae aquifer. The gradient from the HCC well to T-41 is 0.62 ft/mi, and to the Honouliuli monitoring well is 1.75 ft/mi, both of which are somewhat outside the range of expected gradients. In addition, the gradient between the Kunia Well and the HCC well is 0.59 ft/mi which appears low assuming a flow vector due south between the two wells. However, it is important to remember that the direction of groundwater flow between the Kunia Well and the HCC well may have a significant southwesterly component as shown in Figure 3-13. Assuming a SW direction of flow, the perpendicular distance between the equipotentials would be significantly less than the distance between the two wells, and the gradient would therefore be higher than 0.59 ft/mi. This is a possible explanation for the apparently low gradient between the Kunia Well and the HCC Well and is consistent with an interpretation of both wells in the Waianae aquifer. The gradient of 1.75 ft/mi between the HCC well and the Honouliuli monitoring well, however, appears inconsistent with the Waianae aquifer selection for the HCC well. This gradient though may be indicative of a slight steepening in the basal aquifer hydraulic gradient as groundwater approaches the discharge area (i.e. the coast). It is believed more likely that the gradient would steepen in this area than flatten. Under this view, the gradient of 1.75 ft/mi between the HCC well and the Honouliuli monitoring well is not inconsistent with a Waianae aquifer designation for the HCC well. Therefore, while there is some uncertainty, the best estimate is that HCC well is in the Waianae aquifer on the basis of these calculated gradients.

3.5.2.2.2.3 Hydraulic Properties

The performance of the pumping test using the Kunia Well and Basal Well, test analysis and results are summarized in detail in Appendix E. Hydraulic conductivities determined from the test are presented in Table 3-14. As seen in the table, the computed hydraulic conductivity from all the analyses shows a range of approximately half an order of magnitude, from 1,041 to 6,651 ft/day. The higher values (on the order of 6,000 ft/day) were determined from the observation well (Basal Well) data. For these data, the

simulation match to the drawdown curves shows a good match to the start of the test but a relatively poor match to the remainder of the data set due to influences from atmospheric pressure changes which were significant in comparison to the observed drawdown. If these data are excluded, the range of results is about 1000 to 4800 ft/day with a best match at 2300 ft/day. These data (the Kunia Well data) show a reasonable match to the entire data set, and are also consistent with reported values in technical literature.

3.5.2.2.2.4 Kunia Well Assessment

As part of the effort to assess the condition of the Kunia Well and its role as a potential conduit for chemical migration to the basal aquifer, the well was logged using video camera and temperature/fluid resistivity equipment. The results of these investigations are discussed below.

**Video Log.** The Kunia Well was video logged on three separate occasions by Golder and Roscoe Moss. The first video log of the well was conducted March 17, 1997. The log was conducted to a total depth of about 850 ft, or approximately 25 ft below the water table surface. Due to poor quality of the video, however, a second video log was conducted on April 8. This video, which was of good quality, was conducted to the water table surface only. In order to obtain a good quality record of the portion of the well below the water table, on April 24 a third video log was conducted. This log, which was of good quality, was performed to a depth of about 850 ft bgs.

The following observations were made upon review of the video logs:

- Blank casing joints range in length from about 40 to 45 ft. The condition of the blank casing appears to be good, and no water was observed flowing into the well above the screened portion of the well.
- At a depth of 400 ft bgs, the depth scale jumps by 100 ft to indicate 500 ft. Below this point, the depth indicator is off by 100 ft more than the actual depth.
- The screen is first noted at 609 ft bgs. It appears to be a manufactured-type screen, and is heavily corroded. By about 620 ft, the openings are no longer clearly visible due to heavy corrosion. The depth to the top of the screen (609 ft bgs) differs from that indicated elsewhere. ICF (1995b) and HDOH (1996) report a depth to the top of the screen of 626 ft bgs.
- Starting at about 618 ft bgs, distinct vertical lines and shiny areas appear on the screen wall suggesting the possible presence of water, but none is clearly visible, until 674 ft bgs, where the first obvious water flow is evident. A steady stream of water is clearly visible at this depth entering the well through the screen wall. Steady drops are apparent from now on.
- Beyond this point, the flow appears to steadily increase along the casing wall with depth. By 759 ft bgs, there is a very obvious heavy flow along the screen wall.

- The water table surface occurs at about 822 ft bgs, roughly consistent with the value of 824.3 ft measured on March 15, 1997 by Golder field personnel.
- At approximately 850 ft below ground surface, some minor debris is noted in the well. The debris appears to be a piece of metal pipe, electrical cable or some sort of minor metallic material. It is relatively long and slender in shape. It does not appear to be damage to the well or screen.

**Temperature/Fluid Resistivity Log.** The Kunia Well was logged using a temperature/fluid resistivity logging tool on March 19, 1997. The results of the logging are shown in Appendix F and discussed below.

As seen in the temperature/fluid resistivity log included as Appendix F, a zone of relatively constant temperature and fluid resistivity is indicated in the uppermost 20 ft or so of the water column. This is interpreted to be due to the impact of cascading water from above. The cascading water, which is evident in the video log, may serve to maintain this zone at a relatively constant condition. With depth in the water column, the affects of this cascading water are lessened, and the impact of basal aquifer groundwater becomes more dominant. This is evidenced by a more heterogeneous temperature and fluid resistivity distribution (more "noisy") below the upper 20 ft. There is no evidence in the temperature and fluid resistivity profile of significant preferential flow zones in the basalt.

The results of the video and temperature/fluid resistivity logging indicate therefore that water does appear to be cascading into the well from upper saturated zones. These data are combined with the results of the vertical profiling in Chapter 5 to assess the role of the well as a potential conduit for chemical migration.

3.5.2.2.2.5 Basal Aquifer Identification

It is important to determine whether groundwater beneath the Kunia Village Area and at certain key downgradient locations occurs within the Koolau or Waianae volcanic series in order to identify potential downgradient basal aquifer receptors of COPCs. In this section, hydrogeologic information presented in the sections above is reviewed in order to assess whether the relevant aquifer can be identified.

**Stratigraphic Information.**

- **Kunia Village Area.** Stratigraphic information from the Kunia Village Area, consisting of the driller's log of the Kunia Well and a natural gamma log of the Kunia Well, suggest the possible presence of a zone or zones of weathering midway between the ground surface and the water table. A zone of weathering would be expected atop the Waianae basalts prior to their burial by the Koolau basalts. A distinct zone of weathering is indicated by natural gamma logging of the Kunia Well at a depth of about 528 to 584 ft bgs. The driller's log of the Kunia Well indicated a possible weathered zone higher up in a zone from about 304 to 331 ft bgs. These potential weathered zones are suggestive of the contact between the Koolau and Waianae basalts. It is acknowledged that no such

evidence was observed in the Basal Well drill cuttings, however, the Basal Well was drilled with an air rotary drilling rig and therefore the drill cuttings are more difficult to interpret than if the well had been drilled with another method.

- **HCC Well.** A copy of the driller's log for the HCC well is included in Appendix B. The log indicates generally unaltered lava to a depth of 991 ft. From 991 ft to the bottom of the borehole at 1047 ft is a "weathered rock" and "silt". This may represent the Waianae/Koolau unconformity. This would suggest the well may be constructed largely in the Koolau, or possibly across the contact. However, Mr. Chester Lao, hydrologist with the Board of Water Supply, logged this well and noted that the interface between the formations lies at or above the water table (Personal Communication, Mr. Chester Lao, BWS). The extension of the well below the geological contact and the groundwater encountered is therefore most likely within the Waianae aquifer.
- **Honouliuli I/II and Kunia I/II Wells.** The location of the Honouliuli I/II and Kunia I/II wells is shown in Figure 3-14. A copy of the well construction log and drilling log for Honouliuli I well No. 2 (2303-02) is included in Appendix B. This log indicates a zone of "red mud" from about 450 to 500 ft. Fresh dense lava is below. The mud zone is interpreted to represent the Waianae/Koolau unconformity. The well was constructed beneath this layer by grouting off the upper 550 ft of the borehole. Therefore, the well is believed constructed in the Waianae aquifer. The Honouliuli II wells are to the west of the Honouliuli I wells. The depth to the contact between the Waianae and Koolau lavas will be even shallower at the location of the Honouliuli II wells. It is likely therefore that all Honouliuli wells are constructed within the Waianae aquifer.

  If this contact depth is projected to the east to the vicinity of the Kunia I/II wells, it is clear that these wells are completed within the Koolau formation. Even if the contact dips only 5°, the contact is at least 350 ft deeper in the vicinity of the Kunia I and II wells than the depth (of 450 ft bgs) noted in the Honouliuli I well, given the location of the Kunia I and II wells both of which are at least 4000 ft to the east. This would place the depth to the contact at the Kunia I and II wells at least 800 feet below ground surface. The maximum depth, however, of the Kunia II wells is 610 ft, and of the Kunia I wells is 427 ft (Table 3-6).

**Presence of Potential Perched Water at depth in the Basalts.** There are several sources of evidence that locally perched water may occur at depth within the unweathered basalt. Wetness was detected in drilling foam during drilling of the Basal Well at a depth of about 658 to 705 ft bgs. In addition, water is clearly visible cascading into the Kunia Well at approximately the same depth during performance of a video log. The construction of the Kunia Well, with the screened interval extending some 200 ft above the surface of the water table suggests that the driller, when drilling the Kunia Well, observed a zone of saturation in the vicinity of 600 to 700 ft and constructed the well specifically to intercept the zone. The presence of saturated conditions, while at a deeper depth than the weathered zones indicated by the Kunia Well gamma logging and driller's log, suggests a possible former weathered surface of generally lower permeability than the surrounding unweathered basalt. Such a surface could consist of

the contact between the Waianae and Koolau, or a contact between the weathered and unweathered Waianae basalts. Additional discussion of the potential perched zone is included below in Section 3.5.2.2.2.6.

**Projection of the Surface Contact of the Waianae Formation.** Figure 3-21 examines the projected depth of the erosional unconformity to the Kunia Well site based on the mapped surface exposure of the Waianae basalts (Figure 3-4). As seen in Figure 3-4, the exposure of the Waianae basalts occurs approximately 4000 ft to the west of the Kunia Well. The dip of these lavas is believed to be about 3-10°. Dips marked on Figure 3-4 near the Kunia Village Area are about 8°. Based on these dips, the depth to the contact between the two lavas at the Kunia Well/Basal Well location would be no deeper than about 550 ft. At a dip of 8°, the contact would occur at 410 ft. These depths are reasonably consistent with the potential contacts noted in the Kunia Well log and natural gamma log. As the water table is present much deeper than these estimated depths, this would indicate that the basal aquifer occurs within Waianae lavas beneath the Kunia Village Area.

A similar analysis conducted for the Hawaii Country Club (HCC) well is shown in Figure 3-22. The results of this analysis are less clear, however, and indicate that there is a reasonable possibility the HCC Well may be completed in either aquifer or may straddle the contact.

**Water Levels.** As discussed above in Section 3.5.2.2.2.2, evaluation of gradients between the Kunia Village Area basal wells and other downgradient basal aquifer wells indicates the Kunia Well and Basal Well are completed within the Waianae aquifer, consistent with the other lines of evidence. The view is less definitive however for the HCC well yet the best estimate is that it is completed within the Waianae.

The various lines of evidence presented above all indicate that Kunia Village Area basal groundwater occurs within the Waianae volcanic series. It is acknowledged that some of the evidence is speculative and open to possible other interpretations, such as the stratigraphic evidence; however, the preponderance of evidence is such that the conclusion is believed warranted. In addition, the water level information and dip projections of the surface contact, which shows the Kunia Village Area wells to be within the Waianae, is believed reasonably definitive in assigning Kunia Village Area groundwater to the Waianae section.

With respect to the HCC well, there is some uncertainty but the best estimate is that the well is within the Waianae. Analysis of the dip of the contact, based on projections of the surface contact of the Waianae formation (Figure 3-22), indicate the well could be completed within either aquifer. Observations noted in the driller's log suggest the contact may have been encountered below the screened interval. However, analysis of hydraulic gradients between the HCC well and other wells suggests the well is installed within the Waianae. In addition, the well was logged by a local BWS hydrologist who identified the contact between the two formations near the water table surface. Therefore, while there is some uncertainty, it is the professional judgment of the RI authors that the HCC well is completed within the Waianae aquifer.

3.5.2.2.2.6 Flow Along the Koolau/Waianae Contact

As discussed above in Section 3.5.2.2.2.5, it is considered possible that saturated conditions may occur at depth beneath the Kunia Village Area, along the contact of the Koolau/Waianae unconformity. The presence of this perched zone has not been confirmed but is inferred from several separate lines of evidence, and is considered suggestive of the presence of the unconformity. This section provides an interpretation of the flow of infiltrating groundwater to the basal Waianae aquifer through this contact.

Before the Koolau lavas erupted and traveled downslope to the west, the pre-existing surface of the Waianae volcano had been eroded, leaving a topography consisting on a regional scale of valleys and ridges, and on a local scale of depressions, mounds, and other irregular features. The Waianae volcano had been dormant about one million years before its eroded surface was covered by Koolau flows.

The buried Waianae surface is underlain by a zone of weathering tens of feet thick, and in valleys is covered with alluvial sediments. The zone of weathering as well as the sediments have a hydraulic conductivity several orders of magnitude less than the fresh, unweathered basalt. Where the unconformity lies above the water table, which is 20 to 25 ft above sea level, water percolating through the unsaturated Koolau intercepts the low permeability surface, and at the point of contact some penetrates the alluvium and weathered zone of the Waianae while some may move down along the contact.

The overall slope of the contact is about 5 to 8 degrees, but the interface is a lumpy rather than a smooth plain as the result of erosion. The water that flows along the contact eventually infiltrates into the unconformity where it is temporarily perched before draining into the unsaturated fresh Waianae basalt and eventually into the basal aquifer.

Where the geological contact is approximately 300 feet above sea level, as in the vicinity of the Kunia Village Area, groundwater would have to travel approximately 2000 feet along an incline of 8 degrees to reach the water table in the Koolau aquifer. The small volume of infiltration originating in the Kunia Village Area would seep into the irregular surface of the unconformity before it could reach the Koolau water table. At the unconformity it would preferentially drain into the unsaturated Waianae basalt, then the Waianae aquifer. Therefore, any impacts of infiltrating perched aquifer groundwater are restricted to the Waianae aquifer. Also, the area (in plan) of expected impacts in the Waianae basal aquifer would be approximately the same as the area of infiltrating impacted perched groundwater.

3.5.2.2.3 Conceptual Hydrogeologic Model

A conceptual hydrogeologic model is presented herein describing groundwater flow at the Kunia Village Area and in the vicinity. This model is general, and while not accounting for every detail and possibility of groundwater flow, fits the observed data reasonably well and is believed accurate as a tool for understanding general flow patterns, flow velocities, and potential downgradient receptors. One aspect which is not

addressed by this model is whether the Kunia Well is significant as a conduit for chemical migration. This issue is addressed in Chapter 5.

- Surficial soil and saprolite occur to depths of approximately 80 to 100 ft and are underlain by approximately 100 ft of unsaturated, weathered basalt prior to the occurrence of unweathered basalt at 200 ft depth. The perched aquifer is confined to the saprolite material above the weathered basalt.
- Surface soil and saprolites are of relatively low permeability, with horizontal hydraulic conductivity on the order of 0.01 to 1 ft/day and vertical hydraulic conductivity about one order of magnitude less. Surface water runoff is concentrated in the pit area due to local topography. Low hydraulic conductivity of the surface soil and saprolites combined with surface water flow patterns creates locally saturated (perched) conditions in the saprolite in the pit vicinity.
- Horizontal flow in the perched aquifer occurs to the north-northeast. The extent of the perched aquifer is limited however to the general area south of the ephemeral gulch. North of the gulch the aquifer is absent. Flow from the perched aquifer is primarily vertically downward due to the higher permeability of the underlying basalt. Evidence of this downward flow is the high downward gradients (on the order of 0.5 to 1) in the saprolite and absence of saturated conditions in the saprolite north of gulch area. There are no surface seeps of perched aquifer groundwater or points of perched groundwater discharge to surface water.
- Downward migration occurs from the perched aquifer through the unsaturated basalts to the water table. Immediately beneath the saprolite perched aquifer, approximately 100 ft of weathered basalt was encountered prior to the penetration of fresh basalt. The weathered basalt consists of a transitional zone between the saprolite and unweathered basalt with hydraulic properties intermediate between the two materials. Hydrologic data collected during perched aquifer drilling indicate the weathered basalt zone is unsaturated. Hydraulically, it is therefore an element of the unsaturated basalt sequence which extends from the base of the saprolite to the water table surface.
- At depth beneath the Kunia Village Area, there are indications (from Basal Well drill cuttings, natural gamma logging of the Kunia Well and Kunia Well construction) of a possible perched layer. This zone is interpreted to consist of a weathering zone along the Koolau/Waianae contact. Due to the small inclination of the potential contact and its irregular surface, infiltrating perched water which may collect within this zone will preferentially drain through the unconformity to the Waianae basalts and the Waianae basal aquifer below. Any impacts to basal groundwater are therefore limited to the underlying Waianae aquifer.
- The saturated basalt is highly permeable, with groundwater flow at a gradient of about 1 ft/mile. Hydraulic conductivity is on the order of about 2000 ft/day. Effective porosity of the basalts is about 0.05 to 0.10. The best estimate of average groundwater flow velocity in the saturated basalt is on the order of about 1000 to 1500 ft/year or about 3 to 4 ft/day.

- A variety of hydrogeologic data, consisting of Kunia Village Area stratigraphic information, the projected extension of the Waianae surface exposure, and regional water level data, strongly suggest that the basal aquifer beneath the Kunia Village Area occurs within the basalts of the Waianae volcanic series. The groundwater flow direction in the Waianae aquifer is to the south-southwest.
- Within the basal aquifer, flow across the Waianae/Koolau unconformity is from the Koolau to the Waianae due to higher hydraulic heads in the Koolau. Therefore, the Waianae does not discharge to the Koolau. Since impacts from infiltrating perched groundwater are limited to the Waianae aquifer, all potential downgradient receptors are therefore located within the Waianae aquifer only. Discharge of the Waianae would be to downgradient wells, springs, and via leakage through the coastal caprock.
- The HCC well is the nearest well potentially downgradient of the Kunia Village Area (approximately 1.5 miles south). Hydrogeologic data are not definitive as to which aquifer the well is constructed within. However, the best estimate, based on hydraulic gradient data, is that the well is probably completed in the Waianae aquifer. The Honouliuli BWS wells are clearly constructed in the Waianae aquifer, and the Kunia I/II wells (as well as all existing wells to the east of the Honouliuli wells) are constructed in the Koolau aquifer.

Chapter 4

# 4. NATURE AND EXTENT OF CONTAMINATION

This chapter provides a data summary of the relevant analytical results for all completed Remedial Investigation (RI) sampling and compares the analytical results against appropriate screening criteria. This process is used to identify the known source areas and suspected source areas which should be considered in the baseline risk assessment and the Feasibility Study (FS) for the site. The initial evaluation of the analytical data against the appropriate screening criteria provides an estimate of the nature and extent of COPCs detected in the soils and groundwater at the site. The significance of the nature and extent of COPCs will be determined in the baseline risk assessment and FS. These assessments will provide EPA with the required data necessary to evaluate remedial alternatives and select the Remedy for the Site if determined to be appropriate and necessary.

Chapter 2 outlined the data objectives, rationale and approach, sampling methods, sampling locations, and analyses performed to meet overall RI objectives. The first section of this chapter describes the step-wise data management and initial evaluation approach used to estimate the nature and extent of COPCs in the soils and groundwater operable units. The remainder of the chapter provides the relevant analytical results for the soils and groundwater operable units. Table 4-1 presents the COPCs analyzed for during the RI. Tables 4-2 through 4-15 summarize the analytical results of the RI sampling activities. Appendix A presents all of the validated analytical results from the RI sampling activities. Within the tables, the data qualifier of "U" indicates that the compound was not detected at a concentration above the reported value (i.e., "U" signifies non-detect). The "J" qualifier indicates the compound was analyzed for and detected. The associated concentration is an estimate, but the data are usable for decision making purposes.

## 4.1 Data Management and Initial Evaluation Approach

Preliminary COPCs were selected by EPA and the HDOH and were identified in the RI/FS Work Plan (ICF 1997). The targeted compounds were divided into three groups: 1) COPCs - EDB, DBCP, and other chemicals with regular historical usage; 2) Target Compounds for Screening - primarily previously registered soil fumigants and chemicals which were limited in usage; and 3) Non-Site Target Compounds - chemicals which may be migrating in groundwater from non-related surrounding areas to the Site. All of these compounds (24 total), which are listed on Table 4-1, were collectively referred to as COPCs in the RI documents to denote the entire list of chemicals evaluated in the RI.

The analytical methods used in the field and laboratory evaluations were approved by EPA and the State to meet the data quality objectives of the RI. Prior to approval of the analytical methods, the contract laboratory was required to demonstrate that the EPA methods had quantifications limits of at least one-half the drinking water MCLs or residential PRGs for soil. In addition, a laboratory audit was performed by Golder Associates' chemist prior to the start of RI sampling activities for additional assurances of data quality.

In this chapter, concentrations of preliminary COPCs detected during the RI are screened against appropriate regulatory screening criteria as described below. Detected compounds which exceed the screening criteria must be retained as final COPCs for remedial evaluation purposes in the FS and evaluation of exposure pathways in the Baseline Risk Assessment. The data analysis approach for the RI consisted of the following steps:

- **Quality Assurance Project Plan.** As part of the RI process, a QAPP was developed to ensure the accuracy, precision, and completeness of the data to ensure compliance with data quality objectives. Audits were conducted of the analytical laboratories and EPA approved use of the labs.

  The HDOH routinely participated as an observer of the RI sampling activities and collected split samples from the Kunia Well. Weekly and Monthly Progress Reports were required to be submitted to EPA describing activities performed towards completion of the RI. In addition, ICF Kaiser on behalf of EPA conducted split sampling of perched and basal groundwater as part of the quality assurance program.

- **Analytical data validation.** Data validation is a task related to quality assurance which validates the overall correctness and accuracy of the analytical data obtained in the RI. The result is a database of analytical results which have been confirmed through a standard data validation procedure and which are considered useable for decision making purposes. The data validation summary for all RI data is provided in Appendix A.

- **Comparison of analytical data to regulatory criteria.** Once a validated database has been compiled, the data are then compared to the chemical-specific regulatory criteria. The RI/FS Work Plan (ICF 1997) prescribed the use of EPA Region IX preliminary remedial goals (PRGs) and drinking water maximum contaminant levels (MCLs) for comparison to detected concentrations. MCLs and PRGs are conservative maximum concentration levels which have been established by the EPA to be protective of human health and the environment.

  Compounds detected in the soils operable unit are screened against residential PRGs with the exception of any detected petroleum hydrocarbon compounds which are screened against State of Hawaii Tier 1 Action Levels (HDOH 1996b). Groundwater analytical results are screened against Federal drinking water MCLs when available. State MCLs, promulgated under Hawaii Administrative Rule, Title 11, Chapters 11-20, are equivalent to the Federal MCLs with the exception of three compounds - EDB, DBCP and 1,2,3-trichloropropane. The State MCLs for these three compounds are lower than the Federal MCLs; therefore, the State MCLs are used for regulatory screening for these compounds. For those compounds which do not have a State or Federal MCL established, the Tap Water Region IX PRG was used for screening purposes. During the Feasibility Study risk based cleanup levels will be provided for perched groundwater. Soil gas sampling results were converted to an equivalent ambient air concentration using a simple but conservative model. The resulting ambient air concentrations were then compared to EPA Region IX ambient air PRGs.

The RI/FS Work Plan describes a statistically based approach for comparing the mean concentration of chemicals detected in the vadose zone soils to regulatory criteria. As will be described later in this chapter, the frequency of detection for compounds detected in the Kunia Village Area soils was too low to conduct a meaningful statistical analysis. Therefore, the individual detects are compared directly to the aforementioned regulatory criteria.

Using this data analysis approach the nature and extent of chemicals detected in the various site media are described below.

## 4.2 Kunia Village Area

### 4.2.1 Soils Operable Unit Sampling Results

A total of 159 soil samples were collected in the vadose zone or unsaturated soils of the Kunia Spill Area, Former Fumigant Mixing and Former Fumigant Storage Areas. This includes samples collected in the Former Fumigant Mixing Area described in Section 2.2.3.4. EDB, DBCP, and other volatile organic compounds were not detected in vadose zone soils at concentrations above residential PRGs. EDB and 1,2-dichloropropane (1,2-DCP) were detected in one saturated soil sample each, but at concentrations well below residential PRGs. Low levels of EDB were also detected at concentrations below the laboratory method detection limits in three near surface soil samples collected in the Former Fumigant Mixing Area. Other chemicals and PAHs were detected in vadose zone soils but at concentrations well below their respective PRGs or HDOH Tier 1 Action Levels. Table 4-2 presents all of the compounds detected during soil sampling in the Kunia Village Area.

One soil sample from borehole B-1 collected at a depth of 6 feet bgs contained 19,000 mg/kg total petroleum hydrocarbons (TPH). The Hawaii Tier 1 Action Level for TPH is 5,000 mg/kg. PAH compounds detected in the sample were detected at concentrations less than their respective Tier 1 Action Levels. Rather than continue to characterize the small TPH impacted area, DMFP in consultation with the HDOH excavated the TPH impacted soils around borehole B-1 prior to drilling of the downgradient Basal Well. After the excavation activities were completed, the excavation pit cavity was sampled for TPH and PAHs compounds to confirm attainment of applicable Tier 1 Action Levels. The excavated soils were stockpiled on 10 mil polyethylene liner until being transported to Pacific Thermal Services, Inc. for treatment using thermal desorption in compliance with applicable regulations.

Lindane was detected in eight samples with a maximum detected concentration of 11 $\mu$g/kg. Heptachlor was detected in four samples with a maximum concentration of 3.2 $\mu$g/kg. The residential PRGs for lindane and heptachlor are 420 and 99 $\mu$g/kg, respectively. Low levels of TPH were detected in nine samples with a maximum detection of 940 $\mu$g/kg (with the exception of the B-1, 6 ft depth sample discussed above). The only other compounds detected in vadose zone soil samples were the polyaromatic hydrocarbon (PAH) compounds (acenaphthene, naphthalene and fluorene) associated with the B-1, 6 ft depth sample and extremely low levels of toluene detected in several

soil samples from the Former Fumigant Mixing Area. The PAH detections were well below the Tier 1 Action Levels and residential PRGs. The maximum level of toluene detected was 1.1 mg/kg; the PRG for toluene is 520,000 mg/kg.

In summary, only one vadose zone soil sample collected within the top 20 ft of soil in the Kunia Village Area contained a COPC (TPH) in excess of screening levels. The detected TPH impacted soil was excavated and treated at Pacific Thermal Services, Inc. in accordance with HDOH regulations.

### 4.2.2 Results From Additional Soil Sampling in the Former Fumigant Storage Area

Nine additional boreholes were drilled in portions of the Former Fumigant Storage Area where historical data and data collected during the RI indicated that potentially elevated levels of COPCs were present. These boreholes provided data to evaluate the extent of COPCs present in deeper (typically saturated) soils within the Former Fumigant Storage Area. The boreholes also provided data for the design and location of perched groundwater extraction wells associated with the Phytoremediation Treatability Investigation. Soil samples were collected every five or ten feet from each of the boreholes starting at a depth of 25 to 30 feet. The boreholes were drilled until the weathered basalt was encountered which was typically located at a depth of 60 to 70 feet. In two of the boreholes, large cobbles located at a depth of 40 to 45 feet prevented drilling to deeper depths. Figure 2-2b depicts the location of the additional boreholes drilled in the Former Fumigant Storage Area.

Table 4-3 presents the detected compounds from the Treatability Investigation borehole soil sampling in the Former Fumigant Storage Area. In the area of TB-4 and TB-5 (see Figure 2-2b) the highest concentrations of DBCP and DCP were detected at the depths of 30 to 40 feet below ground surface. These results are similar to findings observed during monitoring well drilling and sampling in this area as discussed in Sections 4.2.5.2 and 4.2.5.3. In other areas of the Former Fumigant Storage Area, the highest concentrations of EDB, DBCP, DCP and other COPCs were detected at the bottom of the perched aquifer which coincides with the start of the weathered basalt.

Using the soil data obtained during the Treatability Investigation borehole sampling, estimated perched groundwater concentrations were calculated. Appendix I provides a summary of the calculation method and associated results. As further discussed in Appendix I, the ratio of the calculated pore-water concentration to the solubility of EDB and DBCP indicates that non-aqueous phase liquids (DNAPL) were not present in the collected soil samples.

### 4.2.3 Soil Gas Sampling Results

Four soil gas samples were collected in the Kunia Village Area. Two were collected in the Kunia Spill Area (boreholes B-7 and B-8), and two were collected in the Former Fumigant Storage Area (boreholes B-27 and B-28). All four samples were collected at a depth of approximately 11 feet bgs and were analyzed by the EPA TO-14 analytical

method. Figure 2-2 depicts the location of the four boreholes. Boreholes B-7, B-8, B-27 and B-28 were selected for soil gas sampling because they were anticipated to be located in areas having the greatest concentration of COPCs. EPA's oversight consultant, ICF Kaiser, collected two soil vapor samples in November 1997, near boreholes B-7 and B-28.

Table 4-4 presents the detected compounds from the soil gas analyses. Included in this table are EPA Region IX PRG ambient air concentrations which have been converted to parts per billion by volume (PPBv). The PRG values have been converted to PPBv to allow for a comparison of PRGs to the derived maximum site risk values. Results from ICF Kaiser's sampling are provided in Appendix K. ICF Kaiser's analytical results did not differ from results collected during the RI.

Although a number of compounds were detectable in soil gas samples, the concentrations are low and do not represent a human health risk. The primary pathway of exposure to on-site workers and residents is the migration of subsurface vadose zone vapors to ground surface and dispersion into the ambient breathable atmosphere. Concentrations of volatile organic compounds measured in the soil gas are well below a level of concern based on modeled ambient air concentrations, as described below. The following is a description of the rationale and methods used in the soil gas modeling.

Volatile compounds migrate in the soil at the Kunia Village Area primarily by gaseous diffusion. Advection (soil gas air currents) is not significant at the Kunia Village Area because subsurface gases are not being generated (such as via active decomposition in a landfill producing methane), thus causing increased soil gas air pressure to create advective flow. Gas diffusion (migration of a gas due to concentration gradients) in the subsurface environment spreads volatile organic compounds away from original sources resulting in lower concentrations at further distances from the source.

Volatile compounds in subsurface soil gas eventually migrate or diffuse toward ground surface and into the ambient atmosphere. The emission of subsurface volatile compounds to the atmosphere reduces the concentration dramatically, mainly because wind (advective movement of ambient air) is so great relative to soil gas diffusion. This process will result in an average emission rate to the ambient air that is sustained as long as the original source is not significantly depleted.

The emission rate of soil gas volatile compounds to the atmosphere can be estimated with Fick's Law of Diffusion through a porous medium using the following equation:

$$Emission\ Rate = \frac{-\tau_a D_a \theta_{sa} (C_{AA} - C_{SG})}{Z}$$

Where:

| | |
|---|---|
| τa = | tortuosity of porous medium (.2 to .4), |
| Da = | molecular diffusion of gases (almost all are between 0.07 and 0.12 cm2/sec), |
| θSA = | air filled porosity (assume 0.25), |
| CAA = | concentration of volatile compound in ambient air (assume 0 μg/cm3 to maximize emission rate), |

| | |
|---|---|
| CSG = | concentration of volatile compound in the soil gas (μg/cm3), |
| Z = | distance from CSG to the ambient atmosphere or the minimum depth of the soil gas probe ≈ 3 feet or 90 cm, and |
| Emission Rate = | $\mu g/cm^2$ sec. |

From the calculation of emission rate, it is then possible to estimate the concentration that would result in the ambient air. Modeling of such phenomenon can be rigorous or made very simple depending on how exact an answer is required. For the purposes of this RI, estimates are made based on a simple model using input parameters that would conservatively maximize the calculated concentrations in the ambient air at the Kunia Village Area. The equation used in this model is as follows:

$$\textit{Ambient Air Concentration} = \frac{\textit{Downwind Length of Emission Source} \times \textit{Emission Rate}}{\textit{Average Wind Speed} \times \textit{Mixing height}}$$

Where:

| | |
|---|---|
| Ambient Air Concentration = | μg/cm3, |
| Downwind Length of Emission Source = | assumed about 120 feet (3,600 cm) about the width of the spill or former fumigant storage area, |
| Emission Rate = | from previous equation, |
| Wind Speed = | assumed 2.5 miles/hour or about 10 cm/sec. (this is 1/2 the EPA default value for air modeling), and |
| Mixing height = | 6 feet (about 180 cm). This is the EPA normal breathing zone value but is very conservative since it acts like a ceiling and does not allow volatile compounds to disperse higher than 6 feet above the ground over a total path of 500 feet. |

From the results of this model, a Natural Mixing Factor can be calculated by the following:

$$\text{Natural } \textit{Mixing} \text{ Factor (dimensionless)} = \frac{\text{Concentration of Volatile Compound in Ambient Air}}{\text{Concentration of Volatile compound in soil gas from soil gas probes}}$$

The Natural Mixing Factor represents the reduction in concentration in the ambient air due to natural processes. The equation reveals that this mixing factor is independent of the initial soil gas concentration. Although the resulting ambient air concentration is calculated to be higher when the initial soil gas concentration is higher, the ratio is the same regardless of concentration. The Natural Mixing Factor is modified by variations in model conditions such as wind speed or length of emission source.

This simple but very conservative model results in a Natural Mixing Factor less than 0.000025 (2.5E-05). This indicates that a volatile compound having a soil gas concentration of 10 PPBv will result in an incremental increase in the ambient air of

about 0.00025 PPBv. In other words, soil gas concentrations will be reduced about 50,000 times in the ambient air environment. The mixing factor applied to the soil gas constituent concentrations in Table 4-4 indicates all constituents detected are well below levels that are of concern in ambient air.

The low concentrations of volatile organic compounds measured in the soil gas also indicate that soil vapor extraction may not be an effective remedial alternative for vadose zone soils. The absence of COPC compounds detected in Kunia Village Area soils combined with the low VOC levels detected in soil gas sampling, indicates that soil vapor extraction in the low permeability saprolites is not an appropriate remedial alternative to carry through the evaluation process of the FS. Based on these findings, EPA approved cessation of soil gas extraction testing as described in the FSP.

### 4.2.4 Surface Water and Sediment Sampling Results

The purpose of the surface water and sediment sampling activities at the Kunia Village Area was to determine the presence or absence of COPCs in stormwater runoff and sediments in the ephermeral gulch and ravine north of the Former Fumigant Storage Area. Fourteen sediment samples and three storm runoff samples from the ephemeral gulch and one grab sample from the excavation pit were collected and analyzed as described in Chapter 2. Figure 2-15 depicts the surface water and sediment sampling locations.

Surface Water Analytical Results

EDB and DBCP were detected in surface water sample SW-3 collected at the end of a potential stormwater runoff path from the excavation pit at concentrations of 170 $\mu$g/L (EDB) and 0.4 $\mu$g/L (DBCP). The grab sample from the excavation pit contained similar concentrations of EDB and DBCP with detections of 167 and 0.3 $\mu$g/L, respectively. Due to the record rainfall in 1996-97 (more than 50 inches between November 1996 to March 1997), storm water runoff may have occurred from the excavation pit. Bromacil and lindane were also detected in the surface water samples, but at concentrations well below their drinking water screening levels. The analytical results for surface water sampling are presented on Table 4-5.

As mentioned earlier, the surface water samples were taken during a period of extremely heavy rainfall (1.7 inches as measured in a nearby rain gauge). When SW-3 sample was collected the pit water had risen to a historically high level where it may have been high enough to flow out of the Former Fumigant Mixing and Former Fumigant Storage areas and into the stream gulch. Based upon the position where SW-3 was collected, the observed flow path of water from the pit, and the similarity in the analytical results, it is believed that SW-3 was representative of water from the pit and not surface water that would normally flow in the gulch during rain events. DMFP personnel noted that the pit water had never risen to that height at any time since the pit was excavated in 1983. The topography in the Former Fumigant Storage and Mixing area normally directs rainwater runoff from these areas to flow into the pit. In addition,

and as is discussed in Chapter 3, perched groundwater at the site does not discharge to the surface, therefore, water sampled in the gulch is not impacted by any groundwater discharges.

With EPA's approval, DMFP constructed a three-foot high earthen berm to mitigate future potential stormwater runoff from the excavation pit. In addition, two additional surface water samples will be collected from the ephemeral gulch during a period of heavy rainfall. One sample will be collected in the area of SW-3 the other will be collected at prior to culvert going under Kunia Road. The additional data will be provided to EPA as an addendum to this report.

Sediment and Soil Runoff Analytical Results

There were no COPCs detected above PRGs at the eight sediment and four soil runoff sampling locations. Ethylene dibromide and DBCP were not detected in any samples. Low levels of lindane and heptachlor were detected in sediment sample S-3 and a soil runoff sample collected at a depth of 4 ft in borehole B-26 (see Figure 2-15 for sampling locations). The maximum detected values were 4.8 $\mu$g/kg for lindane and 6 $\mu$g/kg for heptachlor. The residential PRGs for lindane and heptachlor are 420 and 99 $\mu$g/kg, respectively. Sediment sample S-3 also had a detected total petroleum hydrocarbon (TPH) concentration of 63 mg/kg. The Hawaii Tier 1 Action Level for TPH is 5,000 mg/kg.

### 4.2.5 Perched Groundwater Sampling Results

The concentrations of COPCs present in the perched groundwater in the Kunia Village Area were measured through the following sample collection activities:

- Groundwater samples collected from the eight piezometers installed in the shallow portions of the perched groundwater system;
- Hydropunch samples collected at 20-foot depth intervals during the drilling of monitoring wells MW-1, MW-2, and MW-3; and
- Several rounds of groundwater samples collected from the six completed monitoring wells and the existing perched extraction Well #9 installed in the Kunia Village Area.

#### 4.2.5.1 Piezometer Sampling Results

Table 4-6 presents the concentration of all compounds detected during piezometer sampling. Ethylene dibromide (EDB) was detected at various concentrations in all eight piezometers. The maximum concentration (104 $\mu$g/L) was detected in P-6; the lowest concentration (0.07 $\mu$g/L) was detected in P-1. DBCP was detected in P-2 at 0.12 $\mu$g/L and in P-8 at 31 $\mu$g/L. The regulatory standard of 0.04 $\mu$g/L, used for EDB and DBCP, is from the Hawaii drinking water standards which is lower than the Federal MCLs of 0.05 $\mu$g/L (EDB) and 0.2 $\mu$g/L (DBCP).

The compounds 1,2-dichloropropane (DCP) and xylene were the only other compounds detected during piezometer sampling. DCP was detected above the MCL of 5 $\mu$g/L only in P-8 which had a DCP concentration of 100 $\mu$g/L.

4.2.5.2 Hydropunch Sampling Results

The vertical distribution of COPCs in the perched groundwater was investigated through the collection of groundwater samples at discrete depth intervals. These samples were collected during the drilling of monitoring wells MW-1, MW-2 and MW-3. Each of these wells represents the three different areas of the Kunia Village Area. MW-1 is in the Kunia Spill Area, MW-2 is on the downgradient edge of the Former Fumigant Mixing Area, and MW-3 is in the Former Fumigant Storage Area.

As can be seen on Table 4-7, EDB, DBCP and DCP were routinely detected in most of the Hydropunch samples above screening values. Included on Table 4-7 are compounds detected in the samples collected immediately following well completion and development. These samples represent the concentration of COPCs at the base of the perched aquifer system. With the exception of the elevated concentration of DBCP detected at a depth of 33 feet bgs in MW-3, the concentrations of COPCs were generally greatest near the bottom of the perched aquifer (i.e., in the completed well). Benzene and 1,2,3-trichloropropane were the only other compounds detected in Hydropunch samples above their respective MCLs. As can also be seen in Table 4-7, MW-1 had generally the lowest detected concentrations of COPCs and MW-3 had the highest.

Elevated DBCP (27,700 µg/L) was detected at a depth of 33 ft bgs at Well MW-3. This concentration exceeds 1% of the DBCP solubility in water (DBCP solubility is about 1,000 mg/L; Table 4-1). Exceedance of 1% of a compound's solubility is typically regarded as indicative of the presence of non-aqueous phase liquid (NAPL) (Cohen et al., 1993).

4.2.5.3 Perched Monitoring Well Sampling Results

As discussed in Section 2.4.1.5, data from the piezometer and Hydropunch sampling were used to select the location and design of additional monitoring wells. Installation of MW-3S provided monitoring of the shallow perched zone near MW-3 at a depth where elevated DBCP was detected in a Hydropunch sample. Drilling of a dry hole in the MW-4 area provided direct evidence that the northeastern lateral extent of the perched groundwater is terminated prior to MW-4. Perched monitoring wells MW-5 and MW-6 provide data on the lateral extent of COPCs in the approximate downgradient direction of the perched groundwater. The final location for MW-5 was made necessary by the presence of boulders in the original location. EPA provided approval for the final location of MW-5, as well as the location for MW-6, during conference calls. MW-5 and MW-6 provided further data to the RI for characterization of the perched aquifer. At the request of EPA, existing perched extraction Well #9, located in the center area of the Former Fumigant Mixing Area was added to the perched monitoring well sampling program to provide data on the presence of COPCs in the perched groundwater in this area. Figure 4-1 depicts the location of each of these

wells and provides a summary of all compounds detected in each well at concentrations in excess of regulatory screening levels. Table 4-8 provides a summary of all compounds detected in the perched zone monitoring wells.

Groundwater samples from MW-1, completed in the Kunia Spill area, consistently had low levels of EDB, DCP, and TCP detected. The detected concentrations of EDB and TCP are slightly above their respective MCL's of 0.04 $\mu$g/L and 0.8 $\mu$g/L. The average EDB and TCP concentration detected in MW-1 during the first six rounds of sampling was 0.62 $\mu$g/L and 1.1 $\mu$g/L, respectively. DBCP has not been detected in MW-1 above the MCL. DBCP was only detected during the June-97 sampling. Lindane is the only other compound that has been detected above the MCL. Lindane was detected at a concentration of 2.1 $\mu$g/L in the Sept-97 sampling round, but was not detected in subsequent sampling rounds.

EDB was detected in Well #9 at concentrations of 0.39 and 0.84 µg/L during the May-98 and Jul-98 sampling rounds, respectively. DBCP was detected in Well #9 at concentrations of 0.031 and 0.1 µg/L during the Dec-97 and Jul-98 sampling rounds, respectively. EDB and DBCP were not detected during the other perched groundwater sampling rounds. Bromacil, diuron and ametryn were the only other compounds detected in Well #9 during any of the sampling rounds. Bromacil was detected during three of the four sampling rounds at a maximum concentration of 0.94 µg/L. The screening level for bromacil is 90 µg/L (EPA Lifetime Health Advisory for drinking water). Both diuron and ametryn were only detected during one sampling round. Diuron was detected at a concentration of 0.48 µg/L, and ametryn was detected at a concentration of 0.39 µg/L. The drinking water screening levels for diuron and ametryn are 73 and 330 µg/L, respectively.

Samples collected from MW-2 have exhibited detectable concentrations of EDB, DBCP, DCP, TCP, and lindane above their respective drinking water screening levels. As can be seen on Figure 4-1, the detected concentrations are greater in MW-2 than in MW-1, but typically less than detected in MW-3 and MW-3S. The compiled data on Table 4-8 indicate that the general concentrations of EDB, DBCP, DCP and TCP detected during the past six sampling rounds appear to be decreasing in MW-2.

Monitoring wells MW-3 and MW-3S, installed in the Former Fumigant Storage Area, contain the highest concentration of COPCs detected in the Kunia Village Area perched groundwater system. MW-3S monitors the upper portion of the perched groundwater system (screen interval of 30 - 40 feet bgs), and MW-3 monitors the bottom of the perched groundwater (screen interval of 62 to 72 ft bgs). The highest concentrations of EDB in the Kunia Village Area were detected in MW-3 at an average concentration of 3,277 $\mu$g/L. The highest concentration of DBCP, DCP and TCP were detected in MW-3S with average concentrations of 57,725; 5,475; and 40 $\mu$g/L; respectively. Benzene and lindane were also consistently detected in both wells above drinking water screening levels. Table 4-8 lists all of the compounds detected in MW-3 and MW-3S during all sampling rounds.

Concentrations of DBCP detected in Well MW-3S (Table 4-8) vary from about 45,000 µg/L to 80,000 µg/L. These concentrations exceed 1% of the DBCP solubility. Consistent with the Hydropunch results at 33 ft depth for MW-3, this is indicative of the potential presence of NAPL in the vicinity of the well. As discussed in Section 4.2.2, evidence of NAPL was not observed in the soil samples collected from the nine treatability investigation borings drilled in the area around MW-3 and MW-3S. This indicates that the observed occurrence of potential NAPL near MW-3S is isolated and limited to a localized area immediately adjacent to the well. However, high concentrations of EDB and DBCP are also present in the area encompassed by TB-2, TB-3, TB-4, TB-5, and TB-6.

The different concentrations observed in these wells and boreholes are likely a result of separate accidental releases of materials that occurred at different times, with different types of materials, and different volumes of release. In the Former Storage Area, the accidental releases were probably small and sporadic due to the storage of COPCs in 30 to 55 gallon drums. The differences in COPC concentrations in the saprolite of the Former Storage Area may be due to individual accidental releases from specific drums or from previous fumigant mixing activities.

The observations in wells MW-3S and MW-3, and boreholes TB-2, TB-3, TB-4, TB-5, and TB-6, do not have any significant effect on our interpretation of contaminant fate and transport due to the limited area impacted with the elevated concentrations observed in those wells.

Wells MW-5 and MW-6 provide information on the concentration of COPCs east of the Former Fumigant Storage Area. As described in Chapter 3, the general horizontal groundwater gradient in the Kunia Village Area is to the northeast towards the ephemeral gulch area. A more easterly gradient is also possible in the area of MW-5 and MW-6. The concentrations of COPCs detected in MW-5 and MW-6 indicate that some lateral migration of COCPs from the Former Fumigant Storage Area has occurred to MW-5 with low concentrations of some COPCs detected in MW-6 as shown on Table 4-8.

EDB, DBCP, DCP and TCP were consistently detected in MW-5 above drinking water screening levels. The average detected concentration of EDB, DBCP and DCP (19.7, 152, and 393 µg/L, respectively) is significantly less than concentrations detected in MW-3 and MW-3S. In groundwater samples collected from MW-6, EDB is the only compound remaining at concentrations above the drinking water screening levels. The average concentration of EDB in MW-6 is 0.15 µg/L. DBCP was detected in MW-6 only during the May-98 and Jul-98 sampling rounds at the respective concentrations of 0.008 µg/L and 0.031 µg/L. TCP was detected in MW-6 only during the Jul-98 sampling round at a concentration of 0.41 µg/L.

Table 4-8A presents a comparison of chemical concentrations detected in EPA's split samples collected in November 1997 to concentrations detected in the associated Remedial Investigation samples. Appendix K provides all of the analytical results associated with EPA's split samples. EPA's analytical results did not significantly differ from those observed in the RI samples.

Figures 4-2 and 4-3 provide cross-sectional views of the average concentrations of EDB, DBCP, and DCP detected in various portions of the Kunia Village Area perched groundwater.

### 4.2.6 Basal Groundwater Sampling Results

Groundwater sampling of the basal aquifer was performed at two wells located at the Kunia Village Area and four regional wells. The Kunia Village Area wells include the Kunia Well and the new downgradient Basal Well (State Well #2703-02) ("Basal Well"). The regional wells include the "Navy Well," Hawaii Country Club (HCC) Well, Well ST12M05 located at the U.S. Air Force's Waikakalaua Fuel Storage Annex (FSA), and Honouliuli II Well 2303-03. Figure 2-17 and 2-18 depict the location of these wells. Section 2.4.2 describes the RI activities conducted at the basal wells.

#### 4.2.6.1 Kunia Village Area Basal Well Sampling Results

Groundwater analytical results were obtained from the Kunia Well during the following activities:

- Vertical profiling in the Kunia Well - point source samples were collected every 10 feet starting at just below the water table surface (827 ft bgs) to a total depth of 967 ft bgs.
- Compound concentration versus pumping duration - samples were collected from the Kunia Well at the beginning of purging and at designated times during continuous pumping.
- Basal groundwater sampling program - the Kunia Well and Basal Well sampling program includes monthly sampling for three months and then quarterly sampling for a one year period.

Vertical Profiling

Table 4-9 presents the compounds detected during vertical profile sampling of the Kunia Well. Vertical profile sampling results were provided to EPA in Technical Memorandum TM-97-2 (Golder 1997c). The uppermost sample was analyzed for the full suite of COPCs, and the remaining samples by method 8260 only. Method 8260 includes every chemical that has been detected in the basal groundwater. The following observations can be made regarding these data:

- EDB, DBCP and 1,2-DCP are the only compounds which were detected in any of the samples collected as part of the vertical profile sampling. DBCP was the only compound detected in the uppermost sample. None of the other COPCs were detected in this sample by the EPA Method 8081, 8310, 8260, or Mod-8015 analytical procedures.
- The EDB, DBCP and 1,2-DCP concentrations from the vertical profile samples are relatively constant with depth, with EDB concentrations falling in the range of about 0.4 to 1 $\mu$g/L, DBCP concentrations falling in the range of 1.2 to 1.8 $\mu$g/L, and 1,2-DCP values in the range of about 1 to 4.5 $\mu$g/L. These levels of 1,2-DCP are less than the MCL of 5 $\mu$g/L.

- A notable exception to the constant concentration profile with depth is the uppermost sample (collected about 3 ft below the water table) which exhibited the lowest EDB, DBCP and 1,2-DCP concentrations measured. The EDB and 1,2-DCP concentrations in the uppermost sample were below the detection limit (<0.02 and <.5 μg/L, respectively). The DBCP concentration in the uppermost sample was 0.74 μg/L. No chemicals were detected in the uppermost sample in the method 8260, 8081, 8310 or Mod-8015 analyses.

These data are evaluated further in Chapter 5 and 6 with regard to the issue of whether the Kunia Well serves as a conduit for vertical migration of COPCs.

Concentration versus Pumping Duration

The concentration of EDB and DBCP detected in groundwater samples from the Kunia Well in relation to the duration of pumping was measured three different times during the RI. Data from the three sampling events are provided on Table 4-10. The three sampling events are summarized below.

- Prior to conducting the aforementioned vertical profiling, approximately 7,500 gallons of water were purged from the Kunia Well. A sample was collected at the start of the purge, and a second sample was collected at the end of the purge. The HDOH also collected a sample at the end of the purge. The samples were analyzed for EDB and DBCP only. EDB and DBCP results from samples collected at the beginning and ending of purging exceeded the MCL of 0.04 μg/L. The sample concentrations measured at the end of purging (0.46 and 1.2 μg/L for EDB and DBCP, respectively) were slightly lower than the concentrations measured at the beginning (0.99 and 1.7 μg/L for EDB and DBCP, respectively). The sample collected by HDOH at the end of purging had good correspondence with Golder's sample. The HDOH results were 0.57 and 1.5 μg/L for EDB and DBCP, respectively.
- The second sampling event was conducted during a three day pumping test performed on the Kunia Well during October 18-20, 1997. Table 4-10 provides the sampling results obtained for each sample collection time interval. Samples collected every hour for the first four hours of pumping showed a steady decline in the concentration of EDB which decreased from 0.17 to 0.05 μg/L in the first four hours. EDB was not detected in samples collected after four hours of pumping. The concentration of DBCP as well as DCP and TCP remained fairly constant throughout the three day test. DBCP ranged from 0.84 to 1.0 μg/L; DCP ranged from below 0.5 to 0.7 μg/L; and TCP ranged from 0.6 to 1.0 μg/L.
- In an attempt to confirm the results obtained during the October 18-20, 1997 pump test, a second test was conducted on November 14-16, 1997. Samples were collected at the start of pumping, and 3.5 hours, 24 hours and 48 hours after the start of pumping. In contrast to the previous test, the concentration of EDB remained fairly constant throughout the pumping ranging from 0.15 to 0.17 μg/L. DBCP also remained fairly constant ranging from 0.79 to 1.2 μg/L. DCP and TCP were not analyzed for during this sampling event.

Kunia Village Area Basal Groundwater Sampling Program

The Kunia Well and the Basal Well were sampled in Oct-97, Nov-97, Dec-97, Jan-97, May-98 and Jul-98. Compounds detected during these sampling rounds are summarized in Table 4-11. EDB and DBCP were detected above the MCL of 0.04 $\mu$g/L in every sampling round except in the sample collected from the Kunia Well on October 20, 1997. This sample is associated with the final sample collected during the October 18-20 pumping test discussed above. With the exception of the Oct-97 sample, the concentration of EDB in the Kunia Well ranges from 0.13 to 0.22 $\mu$g/L. DBCP concentrations detected in the Kunia Well range from 0.7 to 1.4 $\mu$g/L. The concentration ranges of EDB and DBCP detected in the Basal Well were 0.1 to 0.26 $\mu$g/L and 0.66 to 0.93 $\mu$g/L, respectively.

The only other compounds detected in either the Kunia Well or the Basal Well were DCP, TCP, TCE and bromacil. DCP was detected at a concentration of 0.5 $\mu$g/L in the Kunia Well only during the Nov-97 sampling. The MCL for DCP is 5.0 $\mu$g/L. TCP concentrations in the Kunia Well range from 0.7 to 1.0 $\mu$g/L and from non-detected to 0.7 in the Basal Well. The Hawaii MCL for TCP is 0.8 $\mu$g/L. TCE was detected only during the Jul-98 sampling round in the Kunia Well at a concentration of 0.27 µg/L and in the Basal Well at a concentration of 0.26 µg/L. However, these results are questionable since TCE was also detected at a concentration of 0.12 µg/L in the trip blank associated with these samples. The detected concentrations are much less than the MCL for TCE of 5.0 µg/L. Low levels of bromacil were detected in all samples collected from both wells. The maximum bromacil concentration detected in the Kunia Well and the Basal Well were 2.0 $\mu$g/L and 3.2 $\mu$g/L, respectively. The drinking water screening level for bromacil is 90 $\mu$g/L. As such, EDB, DBCP and TCP are the only compounds detected in Kunia Village Area Basal wells above drinking water MCLs. The similarity in the concentrations of compounds detected in the Kunia Well and the Basal Well is not unexpected in consideration of the close proximity of the two wells (150 feet separation). Contaminant fate and transport in the basal aquifer is discussed in Chapter 5.

Table 4-8A presents a comparison of chemical concentrations detected in EPA's split samples collected in November 1997 to concentrations detected in the associated Remedial Investigation samples. Appendix K provides all of the analytical results associated with EPA's split samples. EPA's analytical results did not significantly differ from those observed in the RI samples.

4.2.6.2 Regional Basal Well Sampling Results

Table 4-12 provides sampling results from regional basal wells. COPCs were analyzed for in samples collected from the "Navy Well" sampled in October 1997, January 1998, May 1998 and July 1998. Trichloroethene (TCE) was detected during all four sampling rounds at concentrations ranging from 2.7 to 3 $\mu$g/L. The MCL for trichloroethene is 5 $\mu$g/L. The detected TCE concentration in the Navy Well may be associated with migration of chemicals from the Schofield Barracks Superfund Site. Since 1991, this well which serves as the drinking water source for the Kunia Village has been treated with a Packed Tower Aeration Facility to remove TCE prior to human consumption. In

September 1997, the U.S. Army and Schofield Barracks entered into a Contract with DMFP to provide continued resources for the removal of TCE from Kunia Village's drinking water supply. In 1997, the Agency for Toxic Substances and Disease Registry (ATSDR) concluded that there was no apparent past or current health risks due to exposure to TCE at Schofield. The TCE exposure was significantly less at the Kunia Village and always below MCLs indicating that residents of Kunia Village and DMFP workers were not exposed to health risks associated with the TCE. Due to the availability of the treatment facility and the lack of exposure, TCE will not be considered in the baseline risk assessment for the Site.

The Hawaii Country Club Well was sampled in Nov-97, Feb-98, May-98 and Jul-98. The Hawaii Country Club Well is the closest well located potentially downgradient of the site. EDB, DBCP and other COPCs were not detected in the groundwater samples collected during the Nov-97 sampling round. DBCP was detected during each of three other rounds at concentrations ranging from 0.038 to 0.071 µg/L. DCP and TCP were detected only during the Jul-98 sampling round below the laboratory's practical quantitation limits at estimated concentrations of 0.14 and 0.22 µg/L, respectively. The Hawaii MCLs for DCP and TCP are 5.0 and 0.8 µg/L, respectively. No other compounds were detected in the Hawaii Country Club Well.

Samples were collected from ST12MW05, located at the Waikakalaua Fuel Storage Annex, in February 1998 and tested for the full COPC list of compounds. Trichloroethene, detected at a concentration of 0.5 µg/L, was the only compound detected in Well ST12MW05

The Honouliuli II Well 2303-03 is the next closest potentially downgradient well beyond the Hawaii Country Club Well. The Honouliuli Well battery was sampled in May-98 and July-98. No COPCs have been detected in the Honouliuli Well battery.

TCE was detected in the Navy Well and Well ST12MW05, and DBCP, DCP and TCP were only detected in the HCC Well. However, for comparison purposes, Table 4-12 also provides the analytical results for other compounds detected in Kunia Village Area wells.

## 4.3 Other Potential Source Areas

Chapter 2 of this RI report described the investigative methods that were used to develop the data required by EPA for decision making purposes on the appropriateness of cessation of sampling or the need for further sampling at Other Potential Source Areas. The other potential source areas which were investigated in association with the RI include:

- Perimeter areas of the Kunia Village;
- Former Fumigant Storage Area in Field 32;
- Empty Fumigant Drum Burial Sites;

- Former Underground Storage Tank (USTs) Sites;
- Methyl Bromide Cylinder Site in Field 71;
- Current Soil Fumigant Storage Facility; and
- Excavation Pit Soils Natural Attenuation Area in Field 8.

The remainder of this section will discuss the data collected at each of these other potential source areas. Tables provided in this section present compounds which were detected at least once in each of the different study areas. Appendix A contains summary tables of all analyses and laboratory results performed on collected samples.

### 4.3.1 Perimeter Areas of the Kunia Village Area

Four boreholes were drilled and sampled in perimeter areas of the Kunia Village Area where empty drums appear to have been stored in the past. There were no compounds detected in any of the samples collected.

### 4.3.2 Former Fumigant Storage Area in Field 32

A total of 51 soil samples were collected from nine boreholes drilled in the Former Fumigant Storage Area in Field 32. EDB, DBCP and all other COPCs, except lindane, were not detected in any of the samples. Lindane was detected at a concentration of 11 $\mu$g/kg in only one of the 51 samples. The PRG for lindane in residential soil is 420 $\mu$g/kg. No other compounds were detected in any soil samples collected in the Field 32 Former Fumigant Storage Area.

### 4.3.3 Empty Fumigant Drum Burial Sites

Section 2.2.3.2 details the investigative methods performed at the empty drum burial sites. Compounds detected in the soil samples collected at the Field 60, Field 90 and behind the Poamoho Crateyard empty drum burial sites are presented on Table 4-13. Field 60, Field 90 and behind the Poamoho Crateyard empty drum burial sites represent three different areas of the Oahu Plantation. There were no compounds detected in soil samples from the empty drum burial sites above residential soil PRGs. Bromacil, Lindane, heptachlor, ametryn and diesel were the only compounds detected in any samples. The concentration of these compounds detected at each of the five empty drum burial sites is as follows:

- Field 60 - Geophysical surveys were performed at six of the eight empty drum burial sites in Field 60. Three of the sites were successfully located. A total of 18 soil samples were collected from the three empty drum burial sites in Field 60. Lindane was detected in four samples with detected concentration ranging from 2.7 to 20 µg/Kg. The PRG for lindane is 420 µg/Kg. Bromacil was also detected in four soils samples at concentration ranges of 130 to 570 µg/L. There are no published data available to calculate a PRG for bromacil directly, but terbacil may be used as a surrogate as the two compounds are both uracils and are expected

to have similar toxicological properties. The residential PRG for terbacil is 850,000 μg/Kg. Bromacil is one of the principal commercial herbicides currently used on Oahu Plantation and by other pineapple growers throughout the State of Hawaii. Heptachlor was detected in two soil samples at concentrations of 55 and 73 μg/L which is below the PRG of 99 μg/Kg. Ametryn was detected in two soil samples at concentrations of 1,700 and 1,800 μg/Kg well below the PRG of 490,000 μg/Kg. TPH in the diesel range was detected in one soil sample at a concentration of 323 mg/kg which is also well below the Hawaii Tier I Action Level of 5,000 mg/Kg.

- Field 90 - Heptachlor was detected in one sample from Field 90 at 6.0 μg/kg. The residential PRG for Heptachlor is 99 μg/kg.
- Behind the Poamoho Crateyard - Heptachlor was detected in one sample from the Poamoho Crateyard at 2.3 μg/kg, well below the residential PRG of 99 μg/kg. In addition to soil sample analyses, one soil gas sample was collected from each of the three boreholes completed within the empty drum burial site at the Poamoho Crateyard. Using the same conservative methods and rationale described in Section 4.2.2 above, maximum potential ambient air concentrations were calculated for all compounds detected in the soil gas samples. Table 4-14 provides a comparison of the concentrations to PRGs for ambient air. As can be seen from the table, all concentrations are well below levels that are of concern in ambient air. Soil concentrations were also calculated from the soil gas sampling results. These concentrations were well below any residential PRGs. The calculations are provided in Appendix L.

### 4.3.4 Former Underground Storage Tank (USTs) Sites

Investigation activities conducted at former UST sites are discussed in Section 2.2.3.4. The three sites investigated include the Poamoho Crateyard, Maintenance Building Dip Pan and Field 9 Booster Pump former USTs.

There were no compounds detected in any of the soil samples collected at the Poamoho Crateyard and Maintenance Building Dip Pan former UST sites. Table 4-15 presents the compounds detected in soil samples collected at the Field 9 Booster Pump former UST site. Elevated levels of total petroleum hydrocarbons (TPH) in the diesel range were detected below a depth of 11 feet. The samples collected at 16 feet and 25 feet bgs contained TPH concentrations of 8,600 and 6,400 mg/kg, respectively which is greater than the Hawaii Tier 1 Action Level of 5,000 mg/kg. The other compounds detected in the Field 9 samples (lead, acenaphthene, naphthalene, and flourene) are typically TPH constituents, and were all detected at concentrations less than regulatory screening levels. Perched groundwater was not intercepted during Field 9 UST sampling, and the basal aquifer is anticipated to be at depths greater than at least 600 feet bgs in this area.

Soil removal around the Field 9 Booster Pump was complicated by the need to continue to irrigate the pineapple crops, the presence of a concrete slab, and large irrigation pipes. DMFP has developed a Corrective Action Plan for the Field 9 Booster Pump that

was implemented in September 1998. The Corrective Action Plan consisted of moving the existing aboveground tank, destruction of part of the concrete pad, soil excavation, excavated soil sampling, soil staging, excavation pit confirmation sampling, and pit closure. The excavated soils have been treated by thermal desorption as approved by the HDOH.

### 4.3.5 Methyl Bromide Cylinder Burial Site Near Field 71

As was discussed in Section 2.2.3.5, geophysical surveying was conducted in the area where historical records indicate a cylinder was buried containing approximately 43.5 pounds of methyl bromide. Backhoe excavation was conducted in areas where geophysical survey instruments detected possible subsurface material. There were no indications of the remains of the buried methyl bromide cylinder, therefore, no soil samples were collected. The small amount of methyl bromide gas contained in the buried cylinder (less than 10 percent of what can be applied per acre agriculturally) is unlikely to present an environmental hazard to any media. The PRG for methyl bromide in residential soils is 550,000 $\mu$g/kg. The depth to groundwater in this area is anticipated to be over 600 feet below the potential buried cylinder location. If approved by the EPA and the State no further actions are planned for the methyl bromide cylinder burial site.

### 4.3.6 Current Soil Fumigant Storage Facility

There were no deficiencies or indications of leaks, spills or other releases observed in the current Soil Fumigant Storage Facility during the visual inspections by EPA and Golder. Therefore, in accordance with the Work Plan, no sampling is required at the Current Soil Fumigant Storage Facility.

### 4.3.7 Excavation Pit Soils Natural Attenuation Area in Field 8

A total of 27 soil samples were collected from the nine boreholes drilled throughout the Excavation Pit Soils Natural Attenuation Area in Field 8. There were no COPCs detected in any of the 27 soil samples.

## 4.4 Summary

The following is a summary of compounds detected above regulatory criteria in each of the study areas previously discussed in this Chapter.

- **Kunia Village Area Soil Samples** - With the exception of one soil sample that contained total petroleum hydrocarbon compounds in excess of Hawaii regulatory standards, there were no COPCs detected in vadose zone soil samples above the EPA region IX residential PRGs. The TPH impacted soils have been excavated and treated in accordance with HDOH standards. Soil gas samples collected in the vadose zone did not contain concentrations of volatile organic compounds that would exceed levels of concern in the ambient air.

- **Kunia Village Area Perched Groundwater** - Samples collected from portions of the perched groundwater system beneath the Kunia Village Area indicated the presence of ethylene dibromide (EDB), 1,2-dibromo-3-chloropropane (DBCP), 1,2-dichloropropane (DCP), 1,2,3-trichloropropane (TCP), benzene and lindane in excess of drinking water screening levels (MCLs or PRGs). The concentrations of these compounds are generally lowest in the Kunia Spill Area and the Former Fumigant Mixing Area. The highest detected concentrations are generally detected in the Former Fumigant Storage Area in the vicinity of wells MW-3 and MW-3S.

  Hydropunch sampling of the perched groundwater system in these three areas indicate that concentrations of these compounds are generally highest at the base of the perched groundwater system. One exception to this is the concentrations of DBCP and DCP detected in MW-3S which is installed in the upper portions of the perched aquifer in the Former Fumigant Storage Area. The detected concentrations of DBCP and DCP in MW-3S are greater than the levels detected at the base of the perched aquifer in this area as determined by sampling MW-3. Cis- and trans- 1,3-dichloropropene were detected in Well MW-3S, only during the September 1997 sampling, at concentrations in excess of drinking water screening levels. Levels of DBCP at Well MW-3S and in the Hydropunch sample collected at 33 ft depth at MW-3 exceed 1% of the DBCP solubility. This is generally regarded as indicative of the presence of NAPL (Cohen et al., 1993). Evidence of NAPL was not observed, however, in any other samples collected from the Former Fumigant Storage Area, including the soil samples collected from the nine treatability investigation boreholes drilled around the MW-3S/-3 location. This indicates the distribution of potential NAPL is confined to a relatively small area in the immediate vicinity of Well MW-3S.

- **Basal Aquifer Sampling Results** - The presence of COPCs in the basal aquifer beneath the Kunia Village Area was investigated through the collection of groundwater samples from the Kunia Well and the new Basal Well (State Well #2703-02). Multiple samples have been collected from both wells and tested for the full list of preliminary COPCs assigned in the RI/FS Work Plan (ICF 1997). EDB, DBCP and TCP are the only compounds which have been detected in either well above drinking water standards. The concentrations of EDB and DBCP detected in the Kunia Well ranged from less than the detection limit to 0.22 $\mu$g/L and 0.7 to 1.4 $\mu$g/L, respectively. The concentrations of EDB and DBCP detected in the Basal Well ranged from 0.1 to 0.26 $\mu$g/L and 0.66 to 0.93 $\mu$g/L, respectively. The Hawaii drinking water standard for EDB and DBCP is 0.04 $\mu$g/L. The concentrations of TCP detected in the Kunia Well and the Basal Well ranged from non-detect to 1.0 $\mu$g/L and non-detect to 0.8 $\mu$g/L, respectively. The Hawaii drinking water standard for TCP is 0.8 $\mu$g/L.

  Four regional basal wells were also included in the groundwater sampling program. The "Navy Well", Hawaii Country Club (HCC) Well, Well ST12MW05 at the Air Force Waikakalaua FSA, and Honouliuli Well 2303-03 were sampled in conjunction with the RI. TCE was detected in the Navy Well at a maximum concentration of 3.0 $\mu$g/L. DBCP was detected in the HCC Well at the

concentration of 0.038 μg/L, 0.071 μg/L, and 0.059 μg/L during the February 1998, May 1998 and July 1998 sampling, but was not detected during the November 1997 sampling round. Low levels of DCP and TCP were detected in the HCC Well only during the July 1998 sampling. TCE was detected at a concentration of 0.5 μg/L in Well ST12MW05. No compounds have been detected in the Honouliuli Well.

- **Other Potential Source Areas** - Other potential source areas identified in the RI/FS Work Plan (ICF 1997) were investigated as part of the site RI. With one exception, no COPCs were identified at any of the other potential source areas above screening levels. The one exception to this is the presence of TPH diesel compounds detected near a former underground storage tank located at the Field 9 Booster Pump site. Soil samples collected at depths of 16 ft and 25 ft below ground surface had detected TPH concentrations in excess of the State of Hawaii Tier 1 Action Levels.

# 5. CONTAMINANT FATE AND TRANSPORT ANALYSIS

This chapter assesses the fate and transport of certain key COPCs identified in Chapter 4 to support an evaluation of the potential human health and environmental risks which may be posed by the Del Monte Corporation (Oahu Plantation) Superfund site. In general, this fate and transport analysis includes the following steps:

- Identification of the relevant contaminant exposure pathways. An exposure pathway describes the processes that link a chemical source to a potential receptor. Preliminary exposure pathways and receptors were identified previously in the Site Conceptual Model Technical Memorandum and Work Plan (ICF 1995b; 1997). The significance of these pathways is re-evaluated in this chapter based on the recent data collected during the RI;
- Assessment of the environmental fate of COPCs along these pathways in order to describe the behavior of each COPC in the environmental media in which it is transported. Emphasis is placed on contaminant mobility and persistence. The focus is only on those COPCs which were identified in Chapter 4 to be in exceedance of regulatory screening criteria; and
- Estimation of the resulting exposure point concentrations of COPCs to potential pathway receptors.

These steps are included in the sub-sections below. Results of the fate and transport analysis will be used to evaluate potential threats to human health and the environment in the Baseline Risk Assessment (BRA).

## 5.1 Potential Contaminant Exposure Routes

### 5.1.1 Exposure Pathway Elements

As discussed in the SCM TM (ICF 1995b), the components of an exposure pathway are comprised of the following elements:

- A chemical source;
- A mechanism for release of source chemicals to the environment (e.g. leaching from soil to groundwater);
- An environmental transport medium (e.g. air, soil, water);
- An exposure route (e.g. ingestion, inhalation, dermal adsorption); and
- A point of potential receptor contact with the contaminated medium (the exposure point).

An exposure pathway is complete only if all of the above elements are present. Complete exposure pathways also may include those pathways that are not currently complete but may in the future be complete depending on future land use (i.e., use of groundwater for drinking water purposes in areas where groundwater is not currently

used as a drinking water source). The presence of a complete exposure pathway indicates that human or ecological exposure could have occurred in the past, is presently occurring, or may occur in the future.

### 5.1.2 Preliminary Identification of Exposure Pathways

The SCM TM (ICF 1995b) identified potentially complete exposure pathways for the DMC Superfund site based on current and future land-uses. The following four pathways were identified:

1. **Direct Exposure to COPCs in Soils.** This pathway represents potential exposure of site residents, workers and trespassers to COPCs in on-site soils via dermal contact or incidental ingestion. The pathway was considered potentially complete based on historical soil chemical data. The RI included data collection activities (Chapter 2) to estimate the nature and extent of any soil impacts and the relevance of this exposure pathway.

2. **Airborne Exposure to COPCs in Soils.** This pathway represents inhalation of volatile vapors and air particulates associated with impacted soils. Similarly to direct exposure to COPCs in site soils, the airborne exposure pathway was considered to be potentially complete based on historical soils data. Environmental sampling activities of the RI (Chapter 2) provided data to assess the relevance of this exposure pathway.

3. **Exposure to COPCs in Surface Water.** This pathway represents potential exposure to COPCs in surface water or sediment in the ephemeral gulch adjacent to the pit area. The pathway was considered potentially complete through possible discharge of perched groundwater to the gulch, or via transport of surficial sediment in runoff. At the time of the SCM TM, there was uncertainty regarding the extent of the perched aquifer and the possibility of a linkage to surface water bodies. Surface water, sediment and soil sampling (in areas of surface water runoff) activities were included in the RI (Chapter 2) to assess the significance (completeness) of this pathway.

4. **Exposure to COPCs via Groundwater.** The perched groundwater aquifer is not used as a source of drinking water, however, this pathway represents a potentially complete exposure pathway via discharge to the surface at seeps or springs, or through vertical leakage and discharge to the basal aquifer, where exposure then may result at points of basal groundwater withdrawal.

   Perched aquifer drilling was conducted during the RI (Chapter 2) to assess the potential interaction between perched groundwater and surface water, and also between perched groundwater and basal groundwater. Basal groundwater drilling and sampling of wells in the Kunia Village Area and regional supply wells were conducted (Chapter 2) to assess the nature and extent of chemicals in the basal aquifer.

### 5.1.3 Re-evaluation of Preliminary Exposure Pathways based on RI Data

Data collected in the RI (data collection activities are described in Chapter 2 and analytical results are presented in Chapter 4) allows for a re-assessment of the potential exposure pathways presented in the SCM TM (ICF 1995b). This assessment, presented below, is used to determine which pathways are believed complete and require inclusion in the fate and transport evaluation and Baseline Risk Assessment.

1. **Direct Exposure to COPCs in Site Soils.** In the Kunia Village Area, with the exception of one soil sample that contained total petroleum hydrocarbon compounds above Hawaii regulatory standards, there were no COPCs detected in shallow vadose zone soils above any regulatory screening criteria. These TPH impacted soils were excavated and treated using approved thermal desorption methods, as discussed in Chapter 2. In addition, no COPCs were identified at any of the Other Potential Source Areas with the exception of TPH compounds detected at the Field 9 Booster Pump site. The TPH impacted soils at this location have been removed as a petroleum release and treated using thermal desorption. RI data indicate therefore that this exposure pathway is incomplete as there were no COPCs above regulatory screening criteria in shallow vadose zone soils, and as such does not require further consideration in this RI.

2. **Airborne Exposure to COPCs in on-site soils.** Similarly to the case of direct exposure to soils, RI data do not indicate the presence of a chemical source to the air pathway of human health concern. Soil gas sampling results and a simple but conservative calculation (presented in Chapter 4) to derive resulting ambient air concentrations indicate that levels of volatile organics in the soil gas are insufficient to result in levels that would be of concern in ambient air. Also, as COPCs were not detected in shallow vadose zone soils at concentrations above regulatory screening criteria, there is no source for the particulate dust pathway. No further consideration is required for the air pathway.

3. **Exposure to COPCs in Surface Water.** Perched groundwater does not discharge to surface water as evidenced by the low hydraulic heads in the perched aquifer in the vicinity of the ephemeral gulch, nor were any seeps or springs noted. The detection of COPCs in a surface water sample collected from the ephemeral gulch is believed to be due to sustained record rainfall between November 1997 and March 1998 resulting in extremely high water levels in the excavation pit and overflow to the ephemeral gulch. Further surface water sampling is to be conducted to confirm that surface water is not impacted by perched groundwater. Currently, however, due to the low groundwater heads in the perched aquifer in the vicinity of the gulch there is believed to be no discharge of perched groundwater to surface water. In addition, there were no COPCs detected above screening values in sediment samples or soil runoff samples. Therefore, the surface water pathway related to the ephemeral gulch is not believed to be operative at this time. If upon further sampling, COPCs are detected in surface water at levels above screening concentrations, further consideration of this pathway would be conducted.

COPCs were detected in the pit water itself, however, and this comprises an unlikely but potential direct contact and inhalation exposure pathway which requires further evaluation in the BRA. However, assessment of potential risk associated with this pathway does not require an environmental transport calculation (since pit water is contained and essentially immobile). It is therefore not necessary to address this pathway within the context of this fate and transport analysis.

4. **Exposure to COPCs via Groundwater.** As indicated above for surface water, as long as overflow from the pit is controlled, there is believed to be no linkage between perched groundwater and surface water, and no springs or seeps were noted at the site. Therefore, discharge of impacted perched groundwater to surface water is not a complete pathway. In addition, due to the low yield of the perched aquifer, perched groundwater is not used as a drinking water source on Oahu.

   Since April 1980, the Kunia Well has not been used as a drinking water source. However, hydrogeological investigations conducted as part of this RI have generally confirmed that the perched groundwater (and associated deep vadose zone soils) and basal groundwater do contain COPCs above regulatory screening criteria. The perched groundwater discharges vertically through the base of the saprolite to the unsaturated basalts and eventually the basal aquifer, resulting in the observed occurrences of COPCs in the Kunia Village Area basal wells above MCLs. These chemicals have the potential to migrate to downgradient locations (wells), presenting a potentially complete current or future exposure pathway. In addition, there is the issue of whether vertical migration may also be occurring through the annulus of the Kunia Well, which may serve as a conduit for chemical migration from the perched aquifer to the basal aquifer. As discussed further in Section 5.3.1.1, data indicate that the well does not currently serve as a conduit.

Therefore, the RI data collected indicate that a number of the preliminary routes of potential exposure at the site can be eliminated from further consideration in the RI and Baseline Risk Assessment, or do not need to be addressed in this Chapter. The only remaining route to be evaluated herein is the impact of the perched aquifer on basal groundwater, and the fate and transport of COPCs within the basal groundwater. This exposure route consists of vertical leakage through the unsaturated zone, or possibly migration through the Kunia Well annulus, to the basal aquifer, resulting in levels of COPCs in the basal aquifer above MCLs, followed by possible downgradient migration to receptor points, such as the HCC Well or other downgradient points.

The remainder of this chapter therefore shall consist of a fate and transport evaluation of this exposure pathway. The primary purpose of the fate and transport assessment is to estimate the downgradient extent of possible COPC impacts associated with the current and prior COPC levels believed representative of the chemical source. A key result shall be the anticipated downgradient travel distance at which levels in basal groundwater may exceed MCLs due to basal aquifer impacts. The estimated travel

distances, combined with the understanding of regional hydrogeology, can be used to identify downgradient receptors, if any, within southern Oahu.

## 5.2 Contaminant Fate

### 5.2.1 Chemicals Addressed

As described in the section above, only one of the preliminary pathways (which also requires fate and transport analysis) included in the SCM TM (ICF 1995b) is believed to be complete based on an evaluation of RI data results. This pathway involves the potential exposure to COPCs via groundwater in the basal aquifer. This section describes the environmental fate of those COPCs which are believed relevant to this potential exposure pathway in support of an evaluation of COPC transport in the section following.

Chapter 4 presents the analytical data collected for the basal aquifer. As described in Chapter 4, the presence of COPCs in the basal aquifer beneath the Kunia Village Area has been investigated through the collection of groundwater samples from the Kunia Well and the new Basal Well. Multiple samples were collected from both wells and tested for the full list of preliminary COPCs assigned in the RI/FS Work Plan (ICF 1997). EDB and DBCP were detected above the MCL of 0.04 $\mu$g/L in every sample from the Kunia Well and Basal Well except one (Oct. 20, 1997; Table 4-11). TCP was detected at concentrations both slightly above and slightly below its MCL of 0.8 $\mu$g/L. DCP was detected only twice during regular monitoring but not at concentrations above its MCL of 5 $\mu$g/L. Bromacil was detected at concentrations much less than its PRG of 90 $\mu$g/L As such, EDB, DBCP, and TCP were the only compounds detected in the on-site basal wells above drinking water MCLs.

DBCP is the only COPC detected in the HCC well above the MCL. Concentrations ranged from less than the quantitation limit to 0.071 $\mu$g/L. DCP and TCP were detected at concentrations less than their quantitation limit during the July-98 sampling round in the HCC well.

In the perched aquifer, EDB, DBCP, DCP, TCP, lindane and benzene were observed over their respective MCLs. Of these compounds, however, only EDB, DBCP, and TCP are impacting the basal aquifer at levels above the MCL. Benzene and lindane were not detected in the basal aquifer, and DCP does not occur over the MCL and was detected only twice in the Kunia Village Area basal wells during regular monitoring.

Therefore, the fate and transport analysis will focus primarily on only the four compounds EDB, DBCP, TCP, and DCP. Since concentrations have been declining in the perched aquifer and basal aquifer for some time, no new compounds would be expected to occur above an MCL, nor would the concentrations of these three compounds be expected to increase in the perched or basal groundwater in the future. The cessation of perched groundwater extraction in 1994 is not significant in allowing accelerated migration of chemicals to the basal aquifer since pumping from the perched

aquifer took place on a regular basis since 1984 only from one of the three wells (Well 9) and pumping only affected a very small area in the vicinity of each well. In addition, levels of COPCs have declined considerably in the perched aquifer since the early 1980s (Section 3.2.3.3).

### 5.2.2 Fate Analysis

This section describes the environmental fate of key COPCs for basal groundwater: EDB, DBCP and TCP. The discussion focuses on sorption and degradation, the processes of aqueous contaminant mass reduction which are relevant to the basal groundwater flow path.

Sorption is the process by which a chemical partitions from the dissolved phase and becomes attached to solid phase materials. Nonionic compounds, which include EDB, DBCP and TCP, sorb primarily to the organic fraction of soils (Chiou et al., 1979) and to clay minerals. Degradation is the process of an organic molecule being broken down or becoming smaller by chemical and biological means (Fetter 1993). Degradation can occur abiotically (without microbial mediation) or biotically (with microbial mediation).

Abiotic transformations include hydrolysis, substitution of a halide ion (for example chloride or bromide) for a hydroxyl ion, and dehydrohalogenation, loss of a halide ion. Half-lives as a result of abiotic degradation of halogenated solvents (such as EDB, DBCP and TCP) are generally in the range of years to tens of years and are dependent on the number of halogen ions within the compound (Fetter 1993).

Biotic transformations typically involve oxidations and reductions and require external electron donors or acceptors. For in-situ biotic degradation (or biodegradation) to occur, the subsurface matrix must possess the required redox conditions and nutrients to sustain microbial activity, and the contaminant degrading microbes must be present in sufficient quantities. Biodegradation of halogenated solvents (such as EDB, DBCP and TCP) may depend on cometabolism (EPA 1993). Cometabolism is the coincidental transformation of an organic compound by enzymes or cofactors produced by the microbes during utilization of other substrates within the subsurface. This kind of reaction requires the presence of a substrate for microbial growth, such as naturally occurring organic carbon.

Environmental conditions influencing the type and rate of contaminant reduction reactions that will occur include pH, temperature, oxidation or reduction state (for example, aerobic or anaerobic conditions), microorganisms present, the presence of available substrate if required for cometabolism, and the contaminant concentration. Reaction kinetics are also important because if a transformation reaction is slow, the contaminant may flow from its origin to impact a large area of the aquifer system prior to significant mass reduction (Fetter 1993).

It is important to note that another potential mechanism of mass reduction related to basal groundwater is volatilization since EDB, DBCP and TCP are all volatile organic compounds. Some volatilization of these compounds will occur across the surface of the

basal water table which affords a large surface area for volatile exchange, and during vertical migration through the unsaturated zone from the perched aquifer. This mechanism is not addressed in this fate and transport analysis however because 1) it is generally believed to be relatively minor compared to the other mechanisms, and 2) the chemical transport model chosen herein (as well as most transport models) does not have a means of specifically including it. Exclusion of this mechanism may be considered conservative however since some reduction is occurring in addition to that predicted in this fate and transport analysis.

The information on contaminant fate and transport presented in this section has been obtained with reference to the U.S. Public Health Service's Agency for Toxic Substances and Disease Registry (Syracuse Research Corp. 1980), the Handbook of Environmental Fate and Exposure Data for Organic Chemicals (Sage et al., 1989) and a number of specific studies included in the reference list. Local information has been obtained with reference to investigations conducted by the Water Resources Research Center at the University of Hawaii (Miller et al., 1988; Lau 1987; Orr and Lau 1987). Table 5-1 provides an overview of the relevant chemical and physical properties for each of the contaminants.

#### 5.2.2.1 Ethylene Dibromide (EDB)

Ethylene dibromide (EDB) was introduced by Dow Chemical Company in 1946 as a preplant soil fumigant for control of nematodes in pineapple and other crops. Between the mid-1940s and its emergency cancellation in December 1983, EDB was principal soil fumigant used on the Oahu Plantation. In addition to its use as a pesticide, EDB has also been used as an additive (lead scavenger) in leaded gasoline and aviation fuels. In addition to the 1977 spill at the Kunia Well Site, other releases of EDB on Oahu may have occurred in the past due to fuel leaks along a military pipeline from Pearl Harbor to the Waiakakalaua Fuel Storage Annex or from leaking USTs (see Section 3.2).

##### 5.2.2.1.1 Sorption/Mobility

EDB exhibits low to moderate adsorption to soil with measured Koc values ranging from 14 to 160 mL/g (Sage et al. (eds.), 1989; Syracuse Research Corp. 1980). For a study of contaminant transport in Hawaiian soils, Loague et al., 1989 estimated a Koc of 5.7 mL/g for EDB. Since aquifer materials are typically low in organic carbon, sorption is predicted to be low in aquifers. Pignatello and Cohen (1990) report no detectable sorption of EDB after 24 hours equilibration time to unconsolidated aquifer fines containing about 0.05% organic matter as organic carbon and suggest a Kd value of <0.1 mL/g and Koc < 83 mL/g for EDB within an aquifer containing less than 0.1% organic carbon. Assuming fast, linear and reversible sorption, a retardation factor of 2 is estimated for a Kd value of 0.1 mL/g (Pignatello and Cohen, 1990). However, since the organic carbon content of the Oahu basal aquifer is expected to be less than 0.01% (HLA 1996) and since the clay mineral content is also expected to be very low, sorption of EDB is expected to be small to negligible within the Oahu basal aquifer system.

Once sorbed, laboratory and field studies conducted with Oahu pineapple field soils (Lau 1987) indicate that pesticide residues (including EDB and DBCP) are tightly held to soil organic carbon, with a desorption coefficient of more than two orders of magnitude greater than that for sorption. Therefore only a small fraction of sorbed residues in these soils are capable of contributing to groundwater contamination. Lau (1987) concludes that the EDB residues which remain in surface soils on Oahu do not constitute a significant source of future contamination of the deep aquifer due to very slow desorption rates. However, should pesticides be transported below the plow layer, mobility will be significant due to decreasing organic carbon contents. Some weak sorption by clay minerals may retard downward movement through the saprolite (Miller et al., 1988).

5.2.2.1.2 Biodegradation

In laboratory studies, EDB has shown to be degraded by a variety of cultures in soil and shallow aquifer microcosms under aerobic conditions and under conditions of methanogenesis, and other reducing anoxic conditions, such as denitrification and sulphate respiration (Cobb and Bouwer 1991; Pignatello and Cohen 1990). Half-lives for these reactions are reported to be on the order of days in surface soils or sediments, and months in shallow aquifer materials. In hypoxic environments, characterized by the presence of the bisulphide ion ($HS^-$), EDB half-lives ranging between 0.8 - 30 years (Barbash and Reinhard 1989) and 37 to 70 days (Syracuse Research Corp. 1980) have been reported with breakdown to 1,2-dithioethane.

The extent to which EDB may degrade biologically in the basal aquifer is highly uncertain since very little is known about the actual environmental conditions (including pH, temperature, oxidation state, and microbial populations) within the aquifer. Given the very low concentrations present in the groundwater and the low anticipated organic carbon (substrate) content which would be needed for cometabolism, biological degradation is believed to be a slow and possibly inconsequential process in the Pearl Harbor basal aquifer. It is therefore assumed that the transformation half-lives of EDB in deeper aquifers resulting from biodegradation may occur with half-lives measured in years to tens of years.

5.2.2.1.3 Abiotic Degradation

EDB is very stable towards hydrolysis with a reported half-life varying between 8 - 13.2 years at pH 7 and 20°C, 2.5 years at pH 7.5 and 25°C, and 273 years at pH 10 (Sage et al., (eds) 1989). Degradation products include ethylene glycol and vinyl bromide. A case study conducted in Massachusetts on EDB groundwater contamination estimated an EDB half-life of 14 years in the aquifer, assuming only hydrolysis as a reduction mechanism (Pignatello and Cohen 1990). Based on a literature review, Pignatello and Cohen (1990) report temperature dependent hydrolysis half-lives of 2.2 - 15 years (15°C), 8 years (20°C), 1.5 - 2 years (22°C) and 2.5 - 4.1 years (25°C) for EDB. The hydrolysis rates were found to be pH independent between pH 4 to pH 9. Therefore, it appears the half-lives for EDB resulting from abiotic degradation are on the order of about 2 to 15 years.

5.2.2.2 1,2-Dibromo-3-Chloropropane (DBCP)

1,2-dibromo-3-chloropropane (DBCP) was introduced by Dow Chemical Company and the Shell Chemical Corporation in 1956 as a preplant soil fumigant for control of nematodes in pineapple and other crops. It was commonly used in combination with Telone or Shell D-D soil fumigant. The compound was typically injected into the soil every three to five years in each field where is was applied. It was used on a significant basis between 1959 and 1977 by the Dole Company (Oki and Giambelluca 1987). All uses of DBCP were canceled by EPA in 1979. Maui Pineapple Company continued to use DBCP until 1985 under a Specific Exemption. At the Del Monte Corporation Oahu Plantation, DBCP was used on a small but commercial scale during the late 1960s.

5.2.2.2.1 Sorption/Mobility

The Kd for the adsorption of DBCP onto clay loam is estimated at 0.2 mL/g for the concentration range of 0.5-95 μg/L. The Koc of DBCP in soils with low organic content has been reported between 20 mL/g in soil with 10% moisture and 129 mL/g in an unspecified soil (Syracuse Research Corp. 1980) which indicates high mobility in soil with low organic carbon content. For a study of contaminant transport in Hawaiian soils, Loague et al., (1989) estimated a Koc of 30 mL/g for DBCP. The retardation factor of DBCP in a soil derived from a fine sand has been estimated at 2.1 (Syracuse Research Corp. 1980). Based on studies conducted on Hawaiian soils (Orr and Lau 1987; Loague et al., 1989), a Koc value of 30 to 32 mL/g has been estimated for DBCP.

As indicated above for EDB, DBCP would be expected to be tightly held in surface soils which contain a high organic carbon fraction due to its high desorption coefficient value in organic carbon rich soils. The DBCP desorption distribution coefficient was determined to be high, ranging from 300 to 1,500 mL/g for recently sorbed DBCP and too large to evaluate for DBCP sorbed over 8 years previous to the experiment (Lau 1987). Based on these results, Lau (1987) concludes that the DBCP residues which remain in surface soils on Oahu do not constitute a significant source of future contamination of the deep aquifer due to very slow desorption rates. DBCP present in the basal aquifer, however, will be mobile due to lack of clay mineral and organic carbon surfaces.

5.2.2.2.2 Biodegradation

Under conditions of aqueous aerobic biodegradation, half-lives ranging between 56 to 360 days have been estimated within groundwater (Howard 1991). Anaerobic aqueous biodegradation rates are assumed to be slower, with half-lives ranging between 120 days and 720 days (Howard 1991). Cobb and Bouwer (1991) and Bouwer and Wright (1988) also report some transformation of DBCP under anoxic conditions of sulphate reduction and methanogenesis in biofilm columns, but do not extrapolate these results to aquifer systems. In contrast, Bloom and Alexander (1990) report no degradation of DBCP in groundwater within small scale laboratory experiments. As with EDB, the extent to which biological decay would occur in the Oahu basal aquifer is uncertain due to the low concentrations and probable lack of substrate matter (organic carbon).

5.2.2.2.3 Abiotic Degradation

Extrapolation of laboratory results indicates that DBCP is hydrolyzed with half-lives ranging between 38 and 141 years at 25°C and 15°C, respectively, at pH 7 and 20°C, and 140 days at pH 9 and 25°C (Burlinson et al., 1982; Syracuse Research Corp. 1980). For typical groundwater conditions in California (pH 7.8, 21.1°C), a DBCP hydrolysis half-life of 6.1 years was calculated (Deeley et al., 1991). This study was conducted in the laboratory using aquifer soils and local groundwater and the results extrapolated to reflect conditions expected with the aquifer. Lau (1987) assumed a hydrolysis half-life for DBCP of 38 years for the Oahu basal aquifer.

5.2.2.3 1,2,3-Trichloropropane (TCP)

General industrial uses of TCP included use as a paint and varnish remover, a solvent, and degreasing agent. TCP was an impurity in the Shell D-D soil fumigant and Telone previously manufactured by the Shell Chemical Corporation and Dow Chemical Company, respectively. Shell D-D was a major soil fumigant used on Oahu by the Dole and Libby companies between the late 1940s and 1977 (Oki and Giambelluca 1987) and by the Del Monte Corporation at the Oahu Plantation between the mid 1940s and 1960s (ICF 1997).

5.2.2.3.1 Sorption/Mobility

Based on information presented by Syracuse Research Corp (1980), TCP exhibits a low to moderate adsorption to soil with an estimated Koc ranging between 72 to 98 mL/g. For a study of contaminant transport in Hawaiian soils, Loague et al., (1989) estimated a Koc of 7.8 mL/g for TCP.

5.2.2.3.2 Biodegradation

TCP is not expected to undergo significant biodegradation. Under conditions of aqueous aerobic biodegradation, half-lives ranging between 360 to 720 days have been estimated within groundwater (Howard 1991). Anaerobic aqueous biodegradation is expected to be significantly slower, with half-lives ranging between 720 days and 1,440 days (Howard 1991).

5.2.2.3.3 Abiotic Degradation

TCP is stable towards hydrolysis with a reported half-life of approximately 44 years at pH 7.5 and 25°C (Syracuse Research Corp. 1980).

### 5.2.3 Conclusions

While there is uncertainty with respect to the sorption and degradation characteristics of these compounds in Oahu basal groundwater, based on review of available technical literature, the following general conclusions can be drawn:

#### 5.2.3.1 Sorption/Mobility

Near surface soils have a high capacity for sorption of pesticide compounds, and in particular for EDB and DBCP. Residues in this layer are tightly held to soil organic matter. With depth however, soil organic carbon content decreases significantly. Based on a study completed by Lau (1987) on the potential for organic chemical contamination of Oahu groundwater, organic carbon fractions of 1.71 to 3.87 % were determined for Oahu topsoil. Below 2 m, the organic carbon fraction was estimated at <1% for the subsoil, and 0.1% for the saprolite layer. Clay minerals are present with the soil and saprolite layers which may also retard downward movement of contaminants (Miller et al., 1988). In this RI (Table 3-10), organic carbon contents in the saprolite ranged from <0.01% to 0.09%. Organic carbon in the basal aquifer will be less than the values, however. HLA (1996) estimated that the organic carbon content of the basal aquifer basalts would be 0.01% or less.

Due to anticipated negligible organic carbon and a very low clay mineral content, it is assumed in this RI that retardation of EDB, DBCP and TCP is inconsequential in the basal aquifer. This assumption will tend to maximize the potential migration distances predicted for these chemicals in the basal groundwater.

#### 5.2.3.2 Degradation

The available evidence is limited but does suggest that degradation of site COPCs occurs, both by biotic and abiotic means, with probable half-lives on the order of years to tens of years.

Due to the low concentrations of COPCs present in the basal aquifer and the expected absence of significant organic content (needed as a substrate for cometabolism), the biological decay reactions are believed to be very minor with respect to Oahu basalts. There is no direct laboratory or field evidence indicating the occurrence of these reactions in basal groundwater. In contrast, there is a greater likelihood that the abiotic mechanisms are significant and will occur. There is a greater preponderance of field and laboratory data indicating that the abiotic processes are significant. On this basis, EDB half-lives in Oahu basal groundwater are believed to range from about 2 to 15 years, and DBCP half-lives range from about 5 to 40 years. TCP half-lives are less well-know but are expected to be similar to DBCP.

## 5.3 Contaminant Transport of the Groundwater Pathway

This section evaluates the transport of the key COPCs discussed above in the groundwater pathway based on the understanding developed in this RI of site hydrogeology, mechanism(s) of migration to the basal aquifer, and chemical fate. The aim is to estimate the potential receptor point concentrations in the basal aquifer which may occur from the historical basal groundwater impacts.

The focus of the transport analysis is on the basal aquifer, as exposure may occur only via the basal aquifer groundwater. The perched aquifer is not a drinking water source, nor does it have any significant interaction with the surface environment, as discussed in Chapter 3. It is significant only with respect to its potential impacts to the basal aquifer.

The first section below (Section 5.3.1) consists of a conceptual model of basal groundwater impacts. It describes, in a general manner, the mechanism(s) for chemical transport to the basal aquifer, dimensions and concentrations of the source area, the significance of historical pumping of the Kunia Well, and identifies potential receptors based on the conceptual hydrogeologic model presented in Chapter 3. An evaluation of perched aquifer impacts to the basal aquifer, based on current conditions, is included in Section 5.3.2. The next section (Section 5.3.3) discusses the approach and inputs to be used in conducting the basal aquifer transport modeling, and the final section (Section 5.3.4) presents the modeling results.

### 5.3.1 Conceptual Model of Basal Aquifer Groundwater Contamination

This model incorporates site hydrogeological and chemical data to describe the mechanism(s) of chemical impacts to the basal aquifer, identify source area dimensions and depth, estimate the source area concentrations, and identify potential receptors.

#### 5.3.1.1 Source of Chemicals to the Basal Aquifer/Significance of the Kunia Well as Conduit

The data collected during the vertical profiling of the Kunia Well (Table 4-8; Section 4.2.5.1) indicate that levels of detected COPCs are relatively constant with depth in the Kunia Well water column. In addition, the maximum concentrations of chemicals were not observed in the uppermost portion of the water column. In fact, the uppermost sample exhibited the lowest concentrations of chemicals. EDB was not detected in the uppermost sample but was detected in samples below, and DBCP concentrations were lowest in the uppermost sample. If the well serves as a conduit for impacted groundwater from the perched aquifer, the maximum chemical concentrations would have been observed in the uppermost sample in the well, and levels would then be seen to decline with depth below this point. Since this was not observed, the data indicate that cascading water within the Kunia Well, which is evident in video logs of the well, does not currently represent a significant migration pathway for chemicals into the basal aquifer. In addition, as no strong peak concentrations were observed in the water column, such as at the base of the well, there is no evidence of a DNAPL pool or source within the well casing or in close proximity to the well.

It is possible the concentrations observed in the uppermost sample may be the result of a lack of chemicals in water cascading down the well annulus, or of aeration of this water as it moves down the well. Regardless of the mechanism for the reduction, however, the data still indicate the well is not currently acting as a significant conduit for vertical migration of chemicals to the basal aquifer.

The conclusion that the well is not currently a conduit is supported by the historical EDB/DBCP data collected over the period 1980 to 1994, including data collected during several long-term pumping tests in the past, such as were conducted during 1980 and 1993. Chemical data collected during these pumping tests, as well as all historical data, are presented in Section 3.2.3.1 and Appendix G. Table 4-10 includes chemical data collected during a long-term pumping test conducted as part of this RI. Historical data are considered qualitative as previous quality control measures were generally less rigorous than current procedures. Notwithstanding, given the data quantity and reasonable consistency over time, these data are relevant and useable in this RI.

As seen in Appendix G, EDB and DBCP concentrations observed during several pumping tests conducted in 1980 decreased dramatically over the duration of the pumping with rapid reductions of approximately two orders of magnitude very soon after pumping began. Levels eventually reached relatively constant concentrations which were much lower than the initial levels. During the pumping conducted in 1993 and 1997, however, the observed changes in EDB and DBCP were much less dramatic over the period of pumping with the concentrations reaching relatively constant values very near the beginning of pumping.

The reductions observed in 1980 suggest a depletion of relatively high EDB and DBCP water located immediately around the well. This could potentially represent water which originated from the perched aquifer that had moved down the annulus of the well casing and out into the formation. As pumping continued, the concentrations of EDB/DBCP were reduced to levels more reflective of the basal groundwater impacted by infiltrating perched groundwater. These data then are believed to indicate that the well may have served as a conduit in the past, but that currently it does not due to a significant reduction in the levels of chemicals in the overlying perched aquifer near the Kunia Well.

These results are consistent with historical changes in EDB/DBCP levels at nearby perched aquifer Well #3. During the early 1980s, levels of these compounds at Well #3 were typically in the 100s to 1000s of ppb. By the early 1990s, these levels had been reduced to 1 ppb or lower.

Further analysis of historical data from the Kunia Well is shown in Table 3-2. Table 3-2 summarizes average EDB and DBCP concentrations at the beginning and end of pumping for each year 1980 through 1994. The calculation of the average concentrations is conducted in Tables G-2 and G-3 in Appendix G. As seen in Table 3-2, the ratios of the concentration at the beginning of pumping to the concentration at the end of pumping were much higher during the early time periods (early 1980s) than during the later time periods (1990s). Ratios for EDB were as high as about 10 to 30 during the early to mid-1980s. Since 1990, however, the ratio has been equal to about one for EDB. DBCP ratios were about 2 to 5 in the early 1980s but have been approximately equal to 1 since 1982. These data further support the view that the well may have served as a conduit in the past, but that currently it does not. Examination of these data indicate that the well as a conduit was probably most operative as a chemical migration pathway prior to and during the early to mid-1980s. After 1984, when much

of the impacted soils had been removed from the Kunia Village Area, the migration pathway appears to have been less operative but may have persisted through about 1990. After 1990 to current time, the well does not appear to have acted as a significant migration pathway.

Additional data confirming that the Kunia Well does not currently serve as a conduit are provided by the similarity in COPC concentrations between the Kunia Well and the Basal Well (Table 4-11). If the Kunia Well is a source for chemicals migrating to the basal aquifer, the levels would be expected to be higher at the Kunia Well than the Basal Well, which is not the case. Both wells reflect levels of COPCs which are not significantly different from one another.

Therefore, while the Kunia Well may have served as a conduit of chemicals in the past, it no longer is a significant conduit, and does not appear to have served as a conduit since about 1990. This is a period of at least 5 years prior to investigations performed for this RI. Given that groundwater flow through the basal aquifer is on the order of 1,500 ft/year (See Section 3.5.2.1.3) and the source area is on the order of 400 ft by 400 ft in area, the basal aquifer source area beneath the Kunia Village Area has been flushed with numerous pore volumes since the time period when the well may have served as a conduit. Any residual basal aquifer impacts which may have occurred due to migration through the Kunia Well annulus, would have been dispersed from the Kunia Village Area. Given this observation, the lack of data indicating current chemical migration via the Kunia Well annulus, and the extent of COPC impacts observed in the perched aquifer elsewhere in the Kunia Village Area, it is concluded that the current primary remaining source of chemicals to the basal aquifer at the Kunia Village Area is represented only by area wide infiltration through the perched aquifer with vertical leakage to the unsaturated basalts and eventually the basal aquifer water table.

A related issue to the role of the well as a conduit is an assessment of the significance of this pathway to basal aquifer impacts. During the time period the well may have acted as a conduit for chemical migration (prior to 1991), the well was being pumped. Historical pumpage from the well is presented in Section 3.2.1.3 and summarized in Table 3-1. As seen in Table 3-1, during the time period when the well may have acted as a conduit (prior to 1991), annual pumping generally equaled or exceeded about 10 million gals per year. Prior to 1980, when the well was connected to the potable supply, the well was pumped at a much higher rate (average of approximately 250,000 gls/day or about 85,000,000 gls per year). The 10 million gallons per year quantity is consistent with statements in the Work Plan (ICF 1997) that following removal of the well from the potable supply system, the well was pumped a minimum of about 4 to 8 hrs per day twice per week. Pumping of 4 hrs per day twice per week is equivalent to about 8 million gals per year. During every year but one (1986), the annual pumpage from the Kunia Well equaled or exceeded the 8 million gals quantity. Prior to and during the early 1980s when the role of the well as a conduit for chemical migration was most operative, pumping is believed to have equaled 30 million gals or more (Table 3-1). Therefore, since annual pumping generally exceeded at least 8 million gals per year during the time the well may have served as a conduit, a quantity of 4 hrs per day twice per week is considered reasonable and conservative to assume as a typical pumping

schedule. This pumping schedule is used in the paragraph below to determine if pumping was sufficient to contain chemicals which may have reached the basal water table via the conduit pathway.

Given this pumping schedule, the well could be inoperative for a period up to about 4 days. If the groundwater velocity is 1500 ft/year or 4 ft/day (Section 3.5.2.1.3), chemicals which reached the basal water table through the well's annulus would have migrated about 16 ft away from the well prior to the re-start of pumping. Pumping for 4 hours would then remove about 78,000 gals of water at a flow rate of 325 gpm. The volume of water contained within a cylinder around the well with radius 16 ft and height 150 ft is about 75,000 gals if an effective porosity of 8% is assumed. Pumping the well for four hours twice per week would withdraw a greater volume of water than is contained within the cylinder, and would therefore be sufficient to contain chemicals which had reached the basal water table through the Kunia Well annulus. However, this evaluation is considered conservative since pumping was generally more than 4 hours per day twice per week. During some time periods though, pumping may have occurred somewhat less frequently than twice per week, which may have resulted in some chemicals not being contained. These releases would have been short duration, point sources and would have depleted via dispersion over a very short distance from the well.

On this basis, therefore, the pumping of the Kunia Well is believed to have been generally sufficient to have contained most of the chemicals that may have reached the water table through the well annulus. Any chemicals which were not contained would have been rapidly flushed and dispersed. Therefore, the migration of chemicals via the Kunia Well annulus did not comprise a source that would have resulted in widespread impacts to the basal aquifer above the MCL.

The conclusions of this section regarding the role of the Kunia Well as a source of chemicals to the basal aquifer can be summarized as follows:

- The well probably did serve as a conduit for chemicals prior to and during the 1980s. This mechanism contributed the highest concentrations of chemicals prior to and during the early to mid-1980s, but may have persisted with lower concentrations through about 1990. After 1990, however, the well is not believed to have acted as a conduit of chemicals at sufficient concentrations to have caused widespread impacts to the basal aquifer above the MCL.
- Even though the well may have served as a conduit prior to 1991, pumping of the well was sufficient to have contained most of the chemicals which may have reached the water table via the well's annulus. Chemicals which may not have been contained for brief periods would have rapidly dispersed to low concentrations. Therefore, leakage of chemicals through the well's annulus is not believed to have resulted in widespread exceedance of the drinking water MCLs in the basal groundwater.
- The most important mechanism of migration to the basal aquifer, which may have resulted in widespread impacts to downgradient basal aquifer water

quality, is Kunia Village Area-wide infiltration from the perched aquifer, including vertical leakage through the unsaturated basalts to the basal aquifer water table. Impacts to basal groundwater via the Kunia Well annulus were largely contained. Any residual impacts not contained would have been flushed and dispersed by the numerous pore volumes that have moved through the Kunia Village Area basal aquifer source area. Currently observed impacts in the basal aquifer are therefore the result of infiltration of perched aquifer groundwater. This is the mechanism which will be addressed in the transport modeling. The Kunia Well as a point source for chemicals to the basal aquifer will not be addressed in the modeling because pumping of the well contained any chemicals associated with this pathway.

Therefore, considerable data are available that indicate the Kunia Well is not currently serving as a significant migration pathway for chemicals to the basal aquifer. It is important to acknowledge however, that since water is observed to be flowing in the well's annulus, the potential for the well to serve as a conduit remains should EDB and DBCP migration patterns change in the future, such as may occur from pit filling or re-grading. However, the potential for this to occur is considered insignificant. It is unlikely that backfilling the pit and controlling surface water runoff/infiltration in this area would result in changes to chemical migration patterns in the perched aquifer such that it would pose an issue with the Kunia Well as a potential conduit. In fact, such measures will reduce the rate of migration of COPCs from the perched aquifer since infiltration and downward hydraulic gradients will be reduced. Therefore, actions which might be taken as part of remedial activities are not expected to increase the likelihood that the Kunia Well would act as a conduit.

#### 5.3.1.2 Source Area Dimensions

As discussed above, the source of chemicals to the basal aquifer is represented by infiltration of perched aquifer groundwater which contains COPCs. Based on the historical land uses at the site (dimensions of the former fumigant mixing and storage areas, and spill area), the distribution of chemicals measured in the perched aquifer monitoring wells, and the observed termination of the perched aquifer near Well MW-4, the extent of the perched aquifer source of chemicals to the basal aquifer can be defined approximately by the area enclosed within wells MW-1 through MW-6. This represents an area approximately 300 ft by 300 ft in size. As discussed in Section 3.5.2.2.2.6, the potential presence of a perched water zone at depth beneath the Kunia Village Area which may be associated with the contact between Koolau and Waianae basalts, does not result in any significant changes to these estimated dimensions.

#### 5.3.1.3 Effective Basal Aquifer Mixing Zone Depth

As described above, the primary source of chemicals to the basal aquifer is believed to be the Kunia Village Area-wide infiltration of impacted perched groundwater from the former fumigant storage and mixing areas, and spill areas at the site. This water moves vertically downward through the unsaturated basalts to the basal water table, where it then mixes with basal groundwater and migrates laterally away.

Given the relatively rapid rate of groundwater movement in the basal aquifer beneath the Kunia Village Area, infiltrating water from the perched aquifer affects only a relatively thin layer near the surface of the water table, and not the entire upper 150 ft as is suggested by the results of Kunia Well vertical profiling. In order to estimate the depth of the impacted basal groundwater, a simple mixing calculation is conducted below. The results of this calculation are shown in Table 5-2.

The calculation is based on a simple mass balance approach. The flowrate of water per unit surface area infiltrating down through the vadose zone is calculated based on an assumed infiltration rate. This water is then assumed to mix with basal groundwater at the water table surface. Based on the rate with which water can move laterally in the mixing zone, the required thickness of the mixing zone can be calculated. In other words, the calculation determines the thickness of basal aquifer material required to convey laterally the flow rate moving downwards from the vadose zone above. This calculation assumes that vertical flow in the basal groundwater is not significant. This is believed appropriate since basal aquifer vertical hydraulic conductivities are much smaller than horizontal. Vertical conductivities are expected to be from about 10 to 1000 times smaller than horizontal conductivities (See Section 3.5.2.13.).

The maximum quantity of rainfall that could infiltrate to the basal aquifer would be 100% of the annual rainfall which is approximately 36 inches for the Kunia Village Area. In order to be conservative and to account for the possibility that the pit area may serve to collect and concentrate runoff from the surrounding area into one location (i.e., to maximize the quantity of assumed infiltration), it is assumed in this calculation that infiltration is roughly 10 ft of water per year per unit surface area. This represents more than three times the annual precipitation. Conservative values are assumed for basal aquifer hydraulic conductivity (1000 ft/day) and hydraulic gradient (.67 ft per mile) which will maximize the calculated mixing zone thickness. Based on these conservative values for infiltration, hydraulic conductivity and gradient, the estimated mixing zone depth is still less than 1 ft (Table 5-2).

While there is undoubtedly some uncertainty as to the actual mixing depth, this calculation demonstrates that it is likely the impacted thickness of basal groundwater resulting from infiltrating perched aquifer water is small directly beneath the source area. It is therefore believed that a source area thickness of 1 to 10 ft is conservative to assume for the thickness of the impacted groundwater immediately underlying the source.

The determination that the mixing zone thickness is relatively small (from 1 to 10 ft) may seem contrary to the observance, in the vertical profile sampling, that chemicals were evenly distributed in the 150 ft thick well column. However, these two observations are not in fact contrary. The lowest levels of COPCs (from vertical profile sampling) were observed in the uppermost sample, collected within a foot or two of the water table surface. This portion of the water column is likely locally influenced by the presence of cascading water in the well. This cascading water does not contain COPCs, due either to aeration as it moves downward in the well, or a lack of chemical impacts to the source of the cascading water. Therefore, this uppermost sample was relatively un-impacted as compared to samples collected at greater depths in the water column.

Below this uppermost sample, levels of COPCs were relatively constant. Since the Kunia Well is not currently serving as a conduit for chemicals, and any residual chemicals from when the well may have acted as a conduit have long since been dispersed, the source of these chemicals is believed to be area wide infiltration from the perched aquifer. The calculation performed above to estimate the thickness of the zone where infiltrating perched groundwater and basal groundwater mix resulted in a potential mixing zone thickness on the order of only 1 to 10 feet. This would indicate that the upper 150 feet of the basal aquifer is not impacted by chemicals, as could initially be interpreted by vertical profile results. The observed vertical profile distribution is due to the vertical flow in the well caused by the head differences between the upper and lower portions of the screened interval. Since the vertical component of the hydraulic gradient is downward in this portion of Oahu, the uppermost portion of the water table will exhibit a higher hydraulic head than lower portions. The Kunia Well casing provides direct hydraulic connection between zones of higher and lower head. Therefore, water which is present in the casing (in the absence of pumping) will flow downward from top to bottom, and will consist primarily from water which has originated near the water table surface. This flow pattern would result in a distribution of COPCs in the well which is relatively constant with depth, and which is characteristic of the upper, higher head portion of the water table. For this reason, the observed constant distribution with depth in the well casing is not inconsistent with a relatively thin mixing zone below the source area.

Therefore, it is believed reasonable to assume, and also quite conservative, that the thickness of the impacted zone within the basal aquifer resulting from infiltration of perched groundwater is on the order of only 1 to 10 ft, and not the full 150 ft of the Kunia Well's screened interval. This is believed a conservative assumption since 1 to 10 ft is a much greater thickness than is estimated to be necessary to transmit infiltrating water laterally away in the saturated formation.

#### 5.3.1.4 Source Concentration.

The Kunia Well is located directly within or in extremely close proximity to the source area where chemicals reach the basal aquifer. Chemical data obtained from the well are therefore believed to be representative of the source concentrations, regardless of the reasonable uncertainties in the direction of groundwater flow. Even if groundwater flow in the basal aquifer is to the south, southeast, or southwest, groundwater sample data collected from the Kunia Well are reflective of source area concentrations. Figure 5-1 demonstrates the position of the Kunia Well relative to a potential plume under the anticipated range of possible directions of groundwater flow at the site. A capture zone for the well has been calculated based on groundwater modeling presented in Appendix H and is shown in Figure 5-1. The capture zone shown in Figure 5-1 represent the estimated size of the well's capture zone during a typical sampling event. As seen in the figure, the well's capture zone falls within the estimated source area plumes under all possible ranges of flow direction. Concentrations observed in the well therefore can be used to estimate average source area concentrations in the basal aquifer as part of transport modeling.

The conclusion that Kunia Well data can be used to estimate the source zone concentration is further supported by the similarity in concentrations between the Kunia Well and Basal Well (See Table 4-11). Levels measured at the two wells are not significantly different from one another. The wells are believed to be approximately in line with the downgradient flow path away from the source area. The similarity in values between these wells indicates that little attenuation is occurring over the 150 ft flow path distance between the two wells. Analogously, little attenuation would be expected over the distance between the Kunia Well and the center of the source area, i.e. perched zone monitoring Well MW-3, for instance.

As discussed above in Section 5.3.1.3, the thickness of impacted basal groundwater beneath the source area is believed to be less than the entire screened interval of the Kunia Well. Using a conservative calculation, the depth was estimated to be on the order of only 1 to 10 ft. When the Kunia Well is pumped and sampled, however, it draws water from the entire 150 ft thick saturated thickness. Even though the Kunia Well data are believed useable to estimate the source concentrations (based on the capture zone analyses presented above), the impacted layer at the water table surface is thinner than the area affected by pumping. Therefore, the chemical results obtained by pumping the well are lower than the concentrations in the actual impacted layer near the water table surface. Since the vertical profiling results are considered to have been representative of the surface layer, as discussed above in Section 5.3.1.3, the vertical profile results (which are higher in concentration than the results from pumping), are considered more representative of the levels in the near surface impacted layer than those from pumping. EDB measured in the vertical profiling (Table 4-9) is about 1 $\mu$g/L, and DBCP is about 1.5 to 2 $\mu$g/L. During pumping of the well, however, EDB was observed at concentrations of about 0.1 to 0.2 $\mu$g/L, and DBCP was observed at about 0.5 to 1 $\mu$g/L. EDB was observed during the vertical profiling therefore at levels about 5 to 10 times higher than the levels observed during pumping, and DBCP was approximately 2 to 3 times higher during the vertical profiling.

Therefore, while the Kunia Well does provide chemical data representative of the source area due to its close proximity to the source, for modeling purposes the concentrations need to be adjusted to be used as source terms. Additional discussion in this regard is included below in Section 5.3.3.3.1.

5.3.1.5 Impacts due to Current and Prior Concentrations of COPCs.

In evaluating the transport of COPCs in the basal groundwater, there is the issue of 1) addressing any current or future impacts posed by the current COPC concentrations observed in the Kunia Village Area, and 2) any existing impacts which may be posed by the prior (historical) COPC concentrations. The prior levels of COPCs were higher than current, and it is possible that these may have resulted in the occurrence of higher concentrations of COPCs in downgradient basal groundwater.

With regard to the impacts due to current conditions, levels in basal groundwater are expected to decline from those observed currently. Concentrations in the Kunia Well have been declining historically since the early 1980s, and as a result concentrations are

not expected to increase in the future. In the perched aquifer as well, historical sample results (i.e., from the early 1980s) indicated the prior impacts were more widespread and at higher concentrations than current impacts, which also resulted in much higher concentrations in the basal aquifer than are being currently observed. The historical trends in EDB and DBCP in the perched and basal aquifer wells have been consistently downward for nearly 20 years, which is at the upper end of the estimated travel time for migration from the perched to basal aquifer. The observed concentrations in wells MW-3, MW-3S, and boreholes TB-2, TB-3, TB-4, TB-5, and TB-6, which are elevated as compared to other wells and boreholes, are localized. A large portion of the original source was removed from the Kunia Village Area over 15 years ago. In addition, the extraction wells installed for the phytoremediation treatability study will serve to remove COPCs from the perched aquifer in this area. Therefore, there is no reason to expect that COPC concentrations in the basal aquifer will increase. In fact, levels are expected to continue to decline. Any future impacts can therefore be conservatively estimated based on the current conditions.

For impacts posed by prior levels of COPCs, pumping from the Kunia Well may have limited, or even prevented, migration from the Kunia Village Area, depending on the well's pumping rate. The discussion below will evaluate the extent to which historical pumping may have contained chemicals. The purpose of this evaluation is to determine at what point in time, if at all, were chemicals first released from the Kunia Village Area. The levels observed for that time period can then be used in the transport modeling to estimate downgradient migration. It is important to note that this evaluation is separate from the containment assessment performed above in Section 5.3.1.1. The evaluation is Section 5.3.1.1 was related to containment of chemicals which may have migrated to the basal aquifer through the well's annulus. This evaluation is to assess containment of chemicals associated with area wide infiltration.

As discussed in Section 3.2.1.3, prior to April 1980 the Kunia Well was used to supply drinking water to Kunia Village and was pumped on the order of 250,000 gals per day. From 1980 onward until 1994, the well was pumped a minimum of twice weekly for 4 to 8 hours per day. These two pumping durations correspond to equivalent average pumping rates (assuming an equivalent continuous pumping rate) of about 175 and 23 gpm, respectively. Appendix H presents a capture zone analysis of the Kunia Well assuming these flow rates as well as a continuous flow scenario of pumping at the well's typical pumping rate of 325 gpm. The analysis is conducted using the groundwater modeling software Visual Modflow (Waterloo Hydrogeologic Software 1997). Full details of the analysis are presented in Appendix H. As seen in Appendix H, essentially complete capture over the main portion of a plume or assumed source area occurs for the 325 and 175 gpm pumping rates, indicating that pumping at these rates is sufficient to contain basal aquifer chemicals. For the 23 gpm rate, while significant capture may occur, the capture is more limited.

The results of this capture zone analysis indicate that it is possible that capture occurs for each of the pumping rates, or at least partial capture. However, there is the greatest uncertainty with regards to the smallest (23 gpm) rate. While it is considered possible that the 23 gpm rate may have attenuated the plume or resulted in partial or near-

complete containment, in order to be conservative, it shall be assumed in this modeling effort that pumping at 23 gpm was insufficient to contain all basal groundwater chemicals. Under this assumption, impacted groundwater was effectively being contained by the Kunia Well prior to 1980 when the well was used as a potable water supply but was not completely contained after 1980. Evaluation of potential downgradient impacts due to prior levels of chemicals in the basal aquifer at the site will therefore be limited in this Chapter to the time period of 1980 and later. This is a conservative assumption since average pumping after 1980 was at times significantly greater than 23 gpm, especially during the early 1980s when COPC levels were highest in the Kunia Well, and significant containment may have occurred even at the 23 gpm rate.

5.3.1.6 Potential Receptors.

Groundwater beneath the Kunia Village Area occurs within the Waianae aquifer portion of the Pearl Harbor aquifer (as discussed in Chapter 3), which is hydraulically lower in head than the Koolau portion. Any chemicals associated with the site will therefore be confined to the Waianae aquifer, and wells in the Koolau aquifer are not expected to be at risk of chemical impacts. Potential downgradient receptors are located only at points of current or future withdrawals from the Waianae aquifer.

Downgradient wells within the Waianae aquifer include the HCC Well, the Honouliuli wells and other wells further downgradient such as the Barber's Point Shaft (See Section 3.5.2.1). The Kunia I and II wells are in the Koolau aquifer, as discussed in Chapter 3. Table 5-3 presents a calculation of the estimated travel times to the HCC and Honouliuli II wells. These travel times are calculated in an Excel® spreadsheet using the Darcy Flow equation as follows:

$$v = Ki/n, \text{ where}$$

| | | |
|---|---|---|
| $v$ | = | average groundwater flow velocity [L/T] |
| K | = | Hydraulic conductivity [L/D] |
| i | = | Hydraulic gradient [L/L] |
| n | = | effective porosity [V/V] |

An Excel® Add-in program is used, Crystal Ball®, which allows for probabilistic inputs of these parameters. Probabilistic inputs (ranges of likely values) are assumed for the travel time parameters (hydraulic conductivity, gradient, and effective porosity), as seen in Table 5-3. The probabilistic inputs are based on the information presented in Chapter 3. Using the information in Chapter 3, which consists of a combination of literature values and measurements made in this RI, assumed probability distributions (triangular distributions in this case) are presented to describe each parameter. These distributions are then utilized in the spreadsheet to calculate a resulting range of possible travel times to each well. Sorption is assumed negligible in this calculation based on information presented above in Section 5.2.

Since pumping from the Kunia Well prior to 1980 is believed sufficient to have contained chemicals, at least 17 years have passed since chemicals may have first migrated away from the Kunia Village Area (assuming that pumping after 1980 was not sufficient for containment).

As seen in the Table 5-3, the estimated travel times to the HCC Well range from a maximum of about 8.5 years to a minimum of about 1 year. There is a 50% probability that the travel time is less than about 2.8 years, and a 95% probability the travel time is less than about 5 years. As discussed in Section 3.2.3.2, no chemicals were detected above the detection limit at the well until 1993, at least 13 years following the first anticipated releases from the site. Since it is believed probable that the travel time is less than about 5 years, it is considered unlikely that the observed impacts in 1993 and after are attributable to the Kunia Village Area, unless pumping of the Kunia Well was more effective than believed in containing a plume beyond 1980. It is therefore believed possible that impacts to the HCC Well are associated with a source(s) other than the Kunia Village Area, such as the regional DBCP occurrences in basal groundwater (See Section 3.2.3). Given that Koolau aquifer groundwater discharges to the Waianae aquifer and the HCC Well is likely close to the contact between the Koolau and Waianae aquifers, DBCP occurrences in the Koolau could potentially impact the HCC Well, even though the HCC Well is believed constructed in the Waianae.

If pumping after 1980 was more effective than believed at containing or partially containing site chemicals, then the observed 1993 DBCP occurrences at the well could possibly be related to the Kunia Village Area. However, it is by no means certain that the well is located along the downgradient flow path from the Kunia Village Area. There is also some uncertainty as to whether the well is located in the Waianae aquifer (Chapter 3). The best estimate is that the well is constructed in the Waianae aquifer. If DBCP occurrences at the HCC well are related to Kunia Village Area impacts, levels in the future will only decline from current values since concentrations at the Kunia Village Area have been declining for over 15 years, are expected to continue to decline, and sufficient time has passed since the first observed occurrences in 1993 for the main front of the plume to have passed (based on the above travel time calculation). DBCP was detected sporadically since 1993 by the HDOH. Since late 1996 and throughout 1997, DBCP has been detected at concentrations ranging from 0.06 to 0.07 $\mu$g/L in HDOH water quality sampling. No COPCs were detected at the well during late 1997 as part of this RI, but DBCP was detected at the well in 1998 (Chapter 4) at levels ranging from 0.038 $\mu$g/L to 0.071 $\mu$g/L.

It is important to note that more effective pumping of the Kunia Well after 1980 than is assumed in this RI, while possibly representing an explanation for the later than expected occurrences of DBCP at the HCC well, would also result in a smaller or less concentrated source term than is being assumed in the transport modeling below.

Travel times to the Honouliuli II wells range from a minimum of about 3 years to a maximum of about 33 years. It is probable (95% probability), however, that the travel time is about 15 years or less. Therefore, it is likely that any impacts would already have occurred at the wells by now, if they were to occur. No COPCs have ever been detected

at these wells including sampling conducted as recently as July 1998. There is some potential that the travel time is greater than 15 years since the total range of the estimated travel times is not less than the 17 years that have elapsed since a potential release may have first occurred. Also, if pumping of the Kunia Well was more effective at containment than is assumed, the travel time to the wells could be delayed (but predicted concentrations would be less). Therefore, there is some uncertainty as to whether there has been sufficient time for chemicals to impact these wells, if they are to do so. The Honouliuli II wells are believed to be in the same aquifer as the Kunia Village Area, but it is not certain whether they are actually located on the same downgradient flowpath.

Other drinking water wells downgradient of the Kunia Village Area beyond the Honouliuli II wells in the Waianae aquifer include the Barber's Point Shaft (2103-03), operated by the US Navy, and the Honolulu Board of Water Supply Makakilo well (2004-04). The Makakilo well is not currently active.

5.3.1.7 Summary

Therefore, to summarize the information discussed above:

- The only significant source of chemicals to the basal aquifer is area wide infiltration of impacted perched aquifer groundwater in the immediate vicinity of the Kunia Village Area. The Kunia Well, while it may have served as a conduit for COPCs in the past, does not currently represent a significant conduit for vertical migration of chemicals to the basal aquifer and has not since about 1990. Even during the time period when the well may have served as a conduit, pumping was sufficient to contain chemicals which reached the basal aquifer via this mechanism. The areal extent of the perched aquifer source to the basal aquifer can be approximated by the area enclosed within wells MW-1 through MW-6. This is an area roughly 300 ft by 300 ft in size.
- The thickness of basal groundwater which is impacted by chemicals infiltrating down from the perched groundwater is believed to be small in relation to the screened interval of the Kunia Well. A conservative estimate suggests it does not exceed a thickness of from about 1 to 10 ft near the water table surface. The entire uppermost 150 ft of the aquifer is not believed impacted. The results of the vertical profiling are interpreted to indicate that water near the surface of the water table, which is believed to possess a higher hydraulic head than water at depth, flows into the well and moves vertically downward creating a constant concentration profile that is more representative of the near surface layer.
- The Kunia Well is located within the source area of COPCs within the basal aquifer, or is extremely close to it, and capture zone analyses confirm that the well draws water primarily from the source area during sampling events. Chemical data obtained from the well can therefore be used to estimate source area concentrations for subsequent transport modeling. Since the well draws water from the entire 150 ft interval, however, and chemicals are believed restricted to the upper 10 ft, levels observed in the well during pumping need to be adjusted (upwards) to reflect the levels considered representative of the

surface impacted layer. The results of the vertical profiling are believed more representative of these levels than those measured during pumping due to the view that near surface water flows into the well and then vertically downward. EDB and DBCP levels measured during vertical profiling were 5 to 10 times and 2 to 3 times levels measured during pumping, respectively.

- Pumping of the Kunia Well prior to 1980, when the well was used as a potable supply well, is believed sufficient to have contained basal aquifer COPCs and prevented migration away from the Kunia Village Area. After this time period, pumping may have been sufficient to result in partial or near-complete containment. However, it is conservatively assumed in this RI that pumping after 1980 was insufficient to contain all chemicals and releases may have occurred after that time. Transport modeling needs to consider the potential impacts therefore only of post 1980 COPCs which infiltrated through the unsaturated basalts to the basal water table. Modeling does not need to consider the Kunia Well as a conduit since pumping of the well was sufficient to contain chemicals which reached the aquifer via this mechanism throughout the time period the well may have acted as a conduit.
- Any potential receptors of chemicals migrating away from the Kunia Village Area are associated with the Waianae aquifer only. Koolau aquifer wells are not at risk as they are hydraulically separated from the Waianae aquifer by the higher heads of the Koolau aquifer and the discontinuity between the Koolau and Waianae basalts. This includes the Kunia I and II wells, which are located in the Koolau aquifer. Potential downgradient receptors therefore include the HCC well, Honouliuli wells, and possibly other Waianae aquifer wells further beyond the Honouliuli wells, if migration is possible to these distances.
- The first observed occurrence of DBCP at the HCC well was in 1993, although there is limited sampling data from the HCC well prior to 1993. Estimates of groundwater travel time from the Kunia Village Area to the HCC well (travel time of about 5 years or less to the HCC well 1.5 miles south of the Kunia Village Area) indicate that DBCP should have been detected at the well earlier than 1993, if it was indeed derived from the Kunia Village Area. It is therefore possible the observed DBCP impacts are not attributable to the Kunia Village Area. Other sources of DBCP are present in Central Oahu which could account for the observances at the HCC well. However, there is a possibility that DBCP at the HCC well is attributable to the Kunia Village Area. For instance, if Kunia Well pumping after 1980 was more effective than assumed at containing DBCP, then the travel time of DBCP to the HCC well could have been delayed, and DBCP occurrences at the well could then be attributable to the Kunia Village Area. However, it is not certain that the HCC well is located on the downgradient flowpath from the Kunia Village Area or is in the same aquifer. Due to these uncertainties, it is not possible to determine whether or not the observed DBCP is associated with the Kunia Village Area. If it is assumed the DBCP occurrences at the HCC well are attributable to the Kunia Village Area, it is unlikely that these levels will increase in the future since sufficient time has passed for the peak concentrations of a potential plume to have reached the well

(based on travel time estimates). Kunia Village Area concentrations have been declining historically. For the Honouliuli II wells, travel time estimates indicate that it is likely chemicals would have already reached the wells, if they were to do so, and yet no chemicals have been observed to date, including sampling conducted as recently as May and July 1998. There is a possibility, albeit small, that insufficient time has passed for chemicals to reach these wells, especially if pumping at the Kunia Well after 1980 was more effective than assumed in containing chemicals. It is uncertain, however, if the wells are located along the flowpath of the Kunia Village Area.

Based on these conclusions, therefore, transport modeling is needed to estimate the downgradient extent of any potential impacts associated with Kunia Village Area chemicals. Modeling will be used to estimate the downgradient distance to which impacts above MCLs are possible from the post 1980 COPC concentrations resulting from infiltrating perched groundwater.

### 5.3.2 Impacts of the Perched Aquifer on Basal Aquifer

This section provides an estimate of the impact of the currently observed COPCs present in the perched aquifer on basal aquifer water quality. Modeling of the transport of basal aquifer COPCs is included below in Section 5.3.3 and 5.3.4.

It is important to note that this estimate represents a qualitative calculation of the flux of perched aquifer chemicals to the basal aquifer. Due to uncertainties in the infiltration rate, travel time, chemical half-lives, and the mass of chemical present, only an approximate assessment is possible. The accuracy of the results is deemed to be order of magnitude or more. A more reliable indication of perched aquifer impacts to basal groundwater is actual basal groundwater data. This calculation serves as a rough check of whether observed groundwater concentrations are representative of the source concentrations.

Table 5-4 presents the calculation of estimated perched aquifer impacts to basal groundwater. The calculation is based on estimating the vertical flux of chemicals (mass/year) moving downward through the vadose zone to the basal aquifer. Upon reaching the basal water table surface, the mass of chemicals is then mixed with the laterally flowing basal aquifer groundwater, resulting in approximate basal aquifer concentrations beneath the perched aquifer source.

The flux estimate from the perched aquifer is based on concentration contour maps presented in Figures 5-2 and 5-3. These maps indicate approximate EDB and DBCP concentrations at the base of the perched aquifer. Groundwater exits the perched aquifer to the unsaturated basalts through the base of the perched aquifer. The maps have been constructed using a combination of measured concentrations from perched aquifer groundwater samples, and also estimated concentrations based on soil data collected during drilling of the treatability investigation borings (Sections 2.2.3.3 and 4.2.2). The estimated groundwater concentrations have been determined using a method outlined in Feenstra et al. (1991) to calculate equilibrium groundwater

concentrations from soil chemical data. The approach used to calculate these values and the calculation results are presented in Appendix I.

Using these perched aquifer groundwater data, approximate order of magnitude concentration contours for the Kunia Village Area perched aquifer are shown in Figures 5-2 and 5-3. The area within each of these contours has been calculated and is shown in Table 5-4.

Figures 5-2 and 5-3 are constructed primarily from wells screened at the bottom of the perched aquifer only. Data from some higher depth zones, such as the depth zone adjacent to well MW-3S, were higher in concentration than at the base of the aquifer, but were not used to create Figures 5-2 and 5-3 or to estimate basal aquifer impacts from perched groundwater because these data are not indicative of levels that are currently exiting the perched groundwater. As discussed in Section 5.3.1.5, the historical trends in EDB and DBCP concentrations in the perched and basal aquifer wells have been consistently declining for nearly 20 years. The observed concentrations in wells MW-3, MW-3S, and borings TB-2, TB-3, TB-4, TB-5, and TB-6, which are elevated as compared to other wells and boreholes, are localized. A large portion of the original source was removed from the Kunia Village Area over 15 years ago. In addition, extraction wells installed for the phytoremediation treatability study will serve to remove COPCs from the perched aquifer in this area. Therefore, there is no reason to expect that COPC concentrations exiting the perched aquifer will increase in the future. In fact, levels are expected to continue to decline. Any future impacts can therefore be conservatively estimated based on the current conditions shown in Figures 5-2 and 5-3.

The calculation of basal aquifer impacts from perched groundwater is based on the assumption that approximately 6 inches of the annual rainfall infiltrates to the perched aquifer and then downward to the basal aquifer. This quantity of infiltration is consistent with the results of several water balance studies presented in available technical literature, i.e., Giambelluca (1986) and HLA (1996). Giambelluca (1986) estimates annual recharge for a "natural" land use receiving 1000 mm precipitation per year (the approximate rainfall for the Kunia Village Area) at about 140 mm or 5.5 inches. A recent USGS report (Shades and Nichols 1996) uses the water balance data of Giambelluca (1986) and derives a similar value. HLA (1996) report infiltration values of approximately 6 to 10 inches per year for the Schofield Plateau. The Kunia Village Area receives about 25% less rainfall per year than the Schofield Barracks area. Therefore, recharge at the Kunia Village Area may be closer to the low end (i.e., 6 inches/year) of these reported values than the high end.

Infiltrating perched water exits the perched aquifer and is assumed to migrate vertically to the basal aquifer at the EDB and DBCP concentrations indicated in Figures 5-2 and 5-3. Based on the assumed infiltration rate and the area within each concentration contour, a total mass of EDB and DBCP flux to the basal aquifer is calculated. As seen in Table 5-4, approximately 155 and 110 g of EDB and DBCP are estimated to reach the basal water table each year, respectively.

Using the values of hydraulic conductivity, gradient and cross-sectional area believed representative of the basal aquifer, a total horizontal flux of basal water is calculated for mixing with these chemicals. The mass of EDB and DBCP are mixed with this flux of water, and a resulting concentration is calculated in the basal aquifer. As seen in the table, concentrations of about 5 and 7 $\mu$g/L are estimated for DBCP and EDB, respectively, assuming no decay or volatilization. These estimates assume a cross-sectional area 400 feet in width by 10 ft deep for the basal aquifer.

This calculation does not account for degradation or volatilization of chemicals as they migrate through the unsaturated zone to the basal aquifer. The time of travel to the basal aquifer and associated degradation will result in lower concentrations than have been estimated here. Therefore, the actual basal aquifer impacts should be lower than the 5 and 7 µg/L concentrations presented in Table 5-4. The time of travel to the basal aquifer is uncertain, but likely varies over a range. On the basis of unsaturated zone modeling presented in HLA (1996), the travel time may be on the order of 10 years. If the travel time is 10 years, the estimated concentrations presented above are reduced to about 3 µg/L for each compound.

This calculation therefore has resulted in estimated EDB and DBCP impacts to the basal aquifer (from current perched aquifer concentrations) of about 5 to 7 $\mu$g/L for the two chemicals. Degradation during travel through the unsaturated zone, which has not been accounted for in this calculation, will result in somewhat lower estimated impacts. This estimate is based on a simple model and is considered accurate to no more than an order of magnitude due to uncertainties in recharge, unsaturated flow, and the variations in perched aquifer COPC concentrations. Therefore, the results are reasonably consistent with the levels measured in the vertical profiling conducted as part of this RI of about 1 $\mu$g/L and 2 $\mu$g/L for EDB and DBCP, respectively, especially considering that degradation has not been accounted for. As discussed earlier in Section 5.3.1.3, the results of vertical profiling are believe more representative of the levels in the near surface mixing zone than analytical results obtained during pumping the Kunia Well. The general similarity between observed and estimated concentrations provides validity to the use of the vertical profile results as estimates of the source area concentration.

### 5.3.3 Basal Aquifer Modeling Approach

#### 5.3.3.1 General

Chemical transport analysis can be performed either analytically or numerically. Numerical models are typically employed in complex cases involving heterogeneous, anisotropic, and/or irregularly-shaped aquifers, or in cases involving complex boundary conditions. However, these conditions are not present in this case. Over the area potentially affected, and considering the scale of the calculation, the Pearl Harbor Basal Aquifer can be assumed to be relatively homogeneous, with a uniform, essentially linear and horizontal flowfield. It is therefore appropriate to model chemical transport from the Kunia Village Area using a relatively simple calculation approach based on an analytical solution. The model BIOSCREEN (EPA 1996) incorporates an analytical

approach which addresses the major transport processes which are relevant to the problem: advection, dispersion, retardation and decay. (BIOSCREEN was developed by the US Air Force Center for Environmental Excellence but is distributed by EPA). Assumptions used in the modeling are presented below in Section 5.3.3.3. The major limitation of the model is that it is essentially a 2-dimensional model with respect to advection and therefore does not address potential vertical migration of COPCs resulting from vertical gradients. It assumes horizontal flow only and provides a centerline output at the water table surface. This limitation however is conservative in that it will result in higher concentrations than would be predicted if vertical flow was considered.

The general approach to the basal aquifer transport modeling is to use the model BIOSCREEN to estimate the downgradient migration of selected COPCs from the Kunia Village Area. Two separate cases of modeling analyses are conducted:

1. Modeling using today's source to estimate future plume migration, and

2. Modeling using the source from 1980 to the present to understand the current potential extent of a plume associated with historical COPC concentrations.

These two sets of modeling analyses are discussed more fully below in Section 5.3.4.

The BIOSCREEN software is an Excel-based tool which utilizes the Domenico (1987) three-dimensional analytical solute transport model. BIOSCREEN assumes a fully-penetrating vertical plane source oriented perpendicular to groundwater flow to simulate the release of organics to moving groundwater. The source is either constant or can be reduced over time using a first-order decay relationship. The Domenico (1987) solution accounts for the effects of advective transport, three-dimensional dispersion, adsorption, and first-order decay.

The authors of BIOSCREEN have modified the Domenico solution to provide three different model types representing i) transport with no decay, ii) transport with first-order decay, and iii) transport with an "instantaneous" biodegradation reaction. In this application, the model is used in the first-order decay mode only.
BIOSCREEN was developed primarily as a tool to evaluate natural attenuation at contaminated sites. One of its intended uses was to simulate remediation through natural attenuation of dissolved hydrocarbons at petroleum release fuel sites, however it is potentially applicable to a variety of organic compounds. As such, it attempts to answer two fundamental questions: 1) How far will the dissolved contaminant plume extend if no engineered controls or further source zone reduction measures are implemented?; and 2) How long will the plume persist until natural attenuation processes cause it to dissipate? For this project, the general aim of using BIOSCREEN is to determine the travel distance in basal groundwater from the Kunia Village Area, for selected key COPCs, to the MCL concentration.

Required model inputs include estimates of source area concentration and dimension (width and depth), hydraulic conductivity, hydraulic gradient, effective porosity, dispersivity (longitudinal, lateral and vertical), retardation, and decay.
The modeling is conducted herein for EDB and DBCP only for the historical modeling runs (Case 2 above), and for EDB, DBCP, TCP and DCP for the predictions of future migration (Case 1 above). These four compounds are the only compounds consistently detected in the basal aquifer at the Kunia Village Area. Historical data are not adequate to model prior occurrences of TCP and DCP.

5.3.3.2 Use of Probabilistic Inputs

An important modification to the BIOSCREEN model has been made by the authors of this RI report for this project. The purpose of the modification is to allow the use of probabilistic inputs (probability distribution functions (PDFs)) for the various model input parameters. Use of PDFs allows for the incorporation of uncertainty into the transport calculation, and the determination of a range of results reflective of this uncertainty. PDFs (normal distribution, for example) are determined based on available information and professional judgment which reflect the anticipated likely range of values for a parameter. PDFs are assigned for parameters such as hydraulic conductivity, porosity and gradient, among others. Rather than merely calculating a single "result" based on discrete inputs, the modified BIOSCREEN model returns a range of results which reflect the assumed PDFs used as inputs. This is a very useful modification because it allows a probabilistic determination of possible downgradient travel distances which are reflective of the range of possible inputs. PDFs which are applied in the modeling are discussed below for each input parameter.

Use of BIOSCREEN in a probabilistic mode (with PDFs as model inputs) is conducted only for the first set of modeling analyses described above in Section 5.3.3.1, i.e. for the case of using today's source to estimate future plume migration. Modeling using the historical source concentrations from 1980 to the present is conducted deterministically, i.e. with discrete values for inputs.

5.3.3.3 Model Inputs (Parameter Estimation)

The following inputs are required in the modeling. The discussion below indicates the assignment of values for each required input. PDFs utilized as model inputs are shown in Figure 5-4. Model inputs and approach for the two different modeling cases are summarized in Table 5-5.

5.3.3.3.1 Source Concentrations

As discussed above in Section 5.3.1.1, due to the pumping history of the Kunia Well, modeling of downgradient impacts from historical COPC levels is performed for the period beginning in about 1980. The discussion below describes the definition of the source term for the historical data.

Kunia Well chemical data are believed representative of the source levels. The data obtained from pumping the well need to be adjusted, however, to reflect the fact that chemicals are present in the source area only in a relatively thin upper layer near the water table surface. In addition, during this time period (after about 1980), the primary mode of COPC movement to the basal aquifer was area wide infiltration of perched groundwater.

Historical data from the Kunia Well are shown in Table 5-6. These data, calculated in Appendix G based on historical data, represent average EDB and DBCP at the conclusion of a pumping period generally of about 4 to 8 hours, for each year since 1980. Concentrations at the conclusion of pumping are assumed more representative of average source area concentrations than values at the beginning of pumping since they are reflective of a wider area, i.e., area wide infiltration, which is the primary mechanism of chemical migration to the basal aquifer. The data shown in Table 5-6 exhibit a decline over time which can be fitted to a first-order decay relationship, using an assumed half-life. The half-life accounts for a variety of source depletion mechanisms, including decay, source removal, and source depletion. As seen in the table, using the fitted relationship, the earliest concentrations (for 1980) are 1.50 $\mu$g/L for EDB and 2.2 $\mu$g/L for DBCP. These values are assumed to be suitable for use at the initial period of modeling.

These values need to be adjusted upwards, however, to reflect the occurrence of COPCs in a near surface layer. Vertical profiling results are believed more representative of the near surface layer than the results obtained during pumping. The validity of the vertical profiling results as estimates of source area concentration is supported by the general agreement between the basal aquifer concentrations estimated in Section 5.3.2 and Table 5-4, and the vertical profiling results.

Based on the results of vertical profiling conducted during the RI, EDB concentrations are adjusted upwards by a factor of ten and DBCP by a factor of 3. This results in an estimated 1980 EDB concentration for the near surface impacted layer of about 15 $\mu$g/L and DBCP concentration of about 6.6 $\mu$g/L.

The decline in concentrations shown in Table 5-6 can be incorporated into the BIOSCREEN model. As seen in Table 5-6, the decline of EDB and DBCP in the basal aquifer can be estimated by a first-order decay relationship with half-lives of about 6 and 12 years, respectively. BIOSCREEN has the ability to include source area decay that is independent of the decay of a downgradient groundwater plume.

Therefore, EDB and DBCP concentrations of 15 and 6.6 $\mu$g/L, respectively, will be used in the modeling to represent the initial concentrations (for 1980). These are assigned to a relatively thin layer near the water table surface. These source levels are then decayed over time to the present based on the first-order decay constants shown in Table 5-6.

The source term for the second main set of modeling analyses (modeling the present day source into the future) is based on vertical profile results measured during this RI, as discussed below in Section 5.3.4.1.

5.3.3.3.2 Source Dimensions

As discussed above in Section 5.3.1.2, the areal dimensions of the source area are approximately 300 ft by 300 ft. In order to account for some lateral spreading of the source as it infiltrates to the basal aquifer, a source zone width perpendicular to the direction of groundwater flow of 400 ft shall therefore be used in the model runs.

A source zone thickness of from 1 to 10 feet shall be used, with an average value of 5 feet, based on the discussion presented in Section 5.3.1.3 regarding the effective mixing zone thickness. The PDF assumed for source zone thickness is shown in Figure 5-4.

5.3.3.3.3 Hydraulic Conductivity

The assumed hydraulic conductivity used in the modeling shall vary between about 1000 ft/day and 3500 ft/day, with a mean value of 2300 ft/day, as shown in Figure 5-4. This is based on the discussion presented in Section 3.5.2.1.3 and 3.5.2.2.2.3.

5.3.3.3.4 Porosity

The assumed effective porosity used in the modeling shall vary between about 0.05 to 0.10 with a mean value of 0.075, as shown in Figure 5-4. This is based on the discussion presented in Section 3.5.2.1.3.

5.3.3.3.5 Hydraulic Gradient

The assumed hydraulic gradient in the basal aquifer shall vary between about 0.67 ft/mile and 1.5 ft/mile with a mean value of 1 ft/mile, as shown in Figure 5-4. This is based on the discussion presented in Section 3.5.2.1.3 and 3.5.2.2.3.

5.3.3.3.6 Dispersivities

Dispersion refers to the process whereby a plume will spread out in a longitudinal direction (along the direction of groundwater flow), transversely (perpendicular to groundwater flow), and vertically downwards due to mechanical mixing in the aquifer and chemical diffusion. Selection of dispersivity values is a difficult process, given the impracticability of measuring dispersion in the field. Field scale dispersion has not been measured in Hawaii's basaltic aquifers, and it is therefore necessary to provide estimated values. Simple estimation techniques based on the length of the plume or distance to the measurement point ("scale") are available in technical literature from a compilation of field test data. Typical dispersivity relationships as a function of Lp (plume length or distance to measurement point in ft) are discussed below.

**Longitudinal Dispersivity** ($Alpha_x$). Based upon a re-evaluation of data originally presented in Gelhar et al., (1992); Xu and Eckstein (1995) proposed the following equation to calculate longitudinal dispersivity as a function of $L_p$, plume length:

$$Alpha_x = 3.28*0.83*(\log10(L_p/3.28))^{2.414}$$

Using potential plume lengths for the site of approximately 5,000 to 30,000 ft results in a range of values of about 50 to 75 feet for $Alpha_x$ using this relationship. Pickens and Grisak (1981) proposed a value of 10% of the plume length as an estimate of longitudinal dispersivity which results in estimated values which are significantly higher (about 500 to 3000 ft).

Typically, longitudinal dispersivity may be considered to be on the order of the same size as the largest flow inhomogeneities within the aquifer materials along the transport reach. Souza and Voss (1987) in a regional groundwater modeling study conducted on Oahu utilized a longitudinal dispersivity of 250 ft for the Pearl Harbor basal aquifer. This value was considered reasonable in light of the size of structures created by lava flows. Voss and Wood (1993) assigned a value of 800 ft to the longitudinal dispersivity in a numerical simulation of regional groundwater flow in the Pearl Harbor aquifer. Longitudinal dispersivity values for the basaltic aquifer on Oahu were estimated to be between 40 ft and 600 ft by Lau and Liu (1983), and between 100 and 200 ft by the USGS (Eyre 1987).

In light of the these values reported in the technical literature, a value of between approximately 100 to 250 ft is believed reasonable to assume for the longitudinal dispersivity, as shown in Figure 5-4.

**Transverse Dispersivity ($Alpha_y$).** Transverse and vertical dispersivity are typically less well known than the longitudinal dispersivity. Transverse dispersivity is often considered to be between about one-twentieth and one-third of the longitudinal dispersivity (Souza and Voss 1987). ASTM (1995) and EPA (1986) suggest estimating $Alpha_y$ as one-third of $Alpha_x$. Based on high reliability points, Gelhar et al.. (1992) assumed a value of 10% of $Alpha_x$ as an estimate of $Alpha_y$. This is the value which shall be assumed in this modeling effort.

**Vertical Dispersivity ($Alpha_z$).** When the plume thickness is of the same size as the aquifer thickness, $Alpha_z$ is estimated to be very low (i.e. 1e-99 ft) (EPA 1996) based on a conservative estimate. This is clearly not the case for this modeling effort as the thickness of the basal aquifer is much thicker (by a factor of many times) than the source. Other commonly used relationships include:

$Alpha_z = 0.05\ Alpha_x$ (ASTM 1995)
$Alpha_z = 0.025\ Alpha_x$ to $0.1\ Alpha_x$ (EPA 1986)

For this modeling effort, $Alpha_x$ shall be estimated as 0.05 $Alpha_x$. It is important to note that BIOSCREEN, with respect to vertical dispersion, only disperses chemicals in the downward direction. In actuality, however, dispersion will occur in both the up and down directions when the plume is below the surface of the water table. Given that there is believed to be a downward vertical gradient in basal groundwater in the vicinity of the Kunia Village, some dispersion would be expected in both the up and down directions. The vertical dispersion which BIOSCREEN estimates may only be about 50% of what actually occurs in the field. Using a vertical dispersivity of 5% of the longitudinal dispersivity is approximately equivalent therefore to about 2.5% of the

longitudinal dispersivity. This value of vertical dispersivity is therefore considered to be on the low end of reported values, and therefore not excessive.

5.3.3.3.7 Contaminant Half-lives

Based on the literature review discussed in Section 5.2, half-lives are assumed to vary between 2 to 15 years and 5 to 40 years with mean values of about 10 and 20 years for EDB and DBCP, respectively. The assumed PDFs used to represent these ranges are shown in Figure 5-4.

In the environmental fate discussion in Section 5.2, TCP behavior with regards to degradation was concluded to be generally similar to DBCP. A fate literature review is not included in Section 5.2, however, for DCP. Given that the degradation properties assumed for DBCP result in the occurrence of very little degradation, and DCP is not excepted to be more recalcitrant than DBCP, the values assumed for DBCP are considered conservative for DCP. Therefore, the half-life assumed for DBCP (a mean value of 20 years with a minimum of 5 years and maximum of 40 years) is also assumed for TCP and DCP.

5.3.3.3.8 Retardation

Based on the literature review discussed in Section 5.2, retardation is assumed negligible in the basal aquifer. Retardation factors of 1 are therefore assumed in all the BIOSCREEN model runs.

5.3.3.3.9 Volatilization

As indicated earlier in Section 5.2.2, loss of constituents due to volatilization is not included in this fate and transport analysis.

### 5.3.4 Basal Aquifer Groundwater Modeling

As indicated earlier in Section 5.3.3.1, two sets of modeling analyses are conducted:

1. modeling of the future downgradient extent of migration from the present-day concentrations observed in the Kunia Village Area (conducted probabilistically for EDB, DBCP, TCP and DCP), and

2. modeling of the present-day downgradient extent of migration from historical concentrations observed in the Kunia Village Area (conducted deterministically for EDB and DBCP only).

Each of these are discussed below. Table 5-5 summarizes the approach and inputs for each of the two sets of modeling analyses.

#### 5.3.4.1 Future Extent of Migration from Currently Observed Impacts

Modeling runs are conducted to estimate the future impacts of existing EDB, DBCP, TCP and DCP concentrations. The probabilistic parameters discussed above are assumed as input parameters, and BIOSCREEN is used in the probabilistic mode developed for this project. For each chemical, the model is run for 3 time periods (5, 10, and 20 years from the present). The result is a series of 3 model runs per chemical.

The assumed source concentrations are based on the results of vertical profiling, which are considered more representative of the near surface impacted layer than the results from pumping. EDB, DBCP, and DCP results during vertical profiling were about 1 $\mu$g/L, 1.5 $\mu$g/L, and 3 $\mu$g/L, respectively (Table 4-9). In order to account for the possibility of some dilution between the central portion of the source and the Kunia Well, these values are conservatively doubled to 2 $\mu$g/L, 3 $\mu$g/L, and 6 $\mu$g/L, respectively. These values are used as the source terms for these chemicals. These EDB and DBCP values are similar in magnitude to the basal groundwater concentrations resulting from perched groundwater impacts calculated in Section 5.3.2.

TCP was not detected during vertical profiling. In samples collected while pumping the Kunia Well and Basal Well, concentrations of 0.7 to 1 µg/L were observed (Table 4-10), approximately equal to those seen for DCP and DBCP. A concentration equal to the DBCP source strength (of 3 µg/L) is therefore specified for TCP for use in the modeling. This is considered conservative because TCP was not detected in any vertical profile samples.

No decay of the source is assumed. Given that levels have declined considerably over the last 15 years, assuming no decay for the future is considered conservative. However, since the declines in recent years have been small, it is not considered appropriate to assume continued declines in the modeling runs.

Output from BIOSCREEN consists of a centerline output. The centerline output is the concentration at the top of the saturated zone (Z=0) along the centerline of the plume's flowpath (Y=0). This concentration represents the maximum concentration with depth assuming the BIOSCREEN model, since vertical dispersion occurs in the downward direction only and flow is horizontal. A typical supply well on Oahu will be screened over a much larger interval than is assumed for the source thickness used in the modeling. Any well installed within the plume will therefore extract water across a zone which exhibits an average concentration which cannot be greater than, and which could in fact be significantly less than, the concentration calculated at the top of the saturated zone (Z=0) by BIOSCREEN. This is an additional inherent conservatism in the modeling approach.

Each model run consists of a series of model realizations (probabilistic realizations). Three-hundred (300) is selected as the number of realizations considered suitable to generate an adequate statistical sampling of the input PDFs. During each model realization, input parameters are selected from the assumed PDFs, and the distance to each chemical's MCL is calculated along the centerline of the plume at the water table

surface. A total of 300 travel distances is therefore generated for each run. This set represents a set of possible travel distances, in essence a calculated PDF, based on the assumed inputs. For each set of travel distance values (for each travel distance PDF), the values are divided into percentiles, or quantiles, and the 90th percentile is determined. For the 90th percentile, 10% of the travel distances lie above the value and 90% lie below.

In addition to the 90$^{th}$ percentile values, the modeling results are also presented in terms of the 95% upper confidence limits (UCL). The UCL is a conservative estimation of the mean and is calculated using the following equation:

$$UCL_{95\%} = X+S*t_{0.05}/Sqrt(n-1)$$

where,

| | | |
|---|---|---|
| X | = | sample mean |
| S | = | sample standard deviation |
| $t_{0.05}$ | = | value of the t distribution at a 5% confidence level |
| n | = | degrees of freedom, i.e. number of samples |

The 95% UCLs and 90$^{th}$ percentile values are both listed in Table 5-7. As shown in Table 5-7, the 90$^{th}$ percentile travel distance values are greater than the UCLs. This is to be expected since the UCL is an estimation of the mean of the results, while the 90$^{th}$ percentile value is more an indicator of the maximum possible value. Because the 90$^{th}$ percentile values represent a reasonable "maximum expected" travel distance for each run, the modeling results are presented herein primarily with reference to the 90$^{th}$ percentile travel distances rather than the 95% UCL of the mean.

The 90th percentile travel distances obtained from the modeling runs are shown in Table 5-7 and Figure 5-5. All output files for these probabilistic model runs are included in Appendix J-1.

#### 5.3.4.2 Results of Modeling of Currently Observed Impacts

The results of the modeling runs for currently observed Kunia Village Area impacts are summarized in Table 5-7 and Figure 5-5. These results represent the 90th percentile travel distances for each run. Based on these data, the following general observations can be made:

- The maximum future estimated travel distance (90th percentile travel distance) from the Kunia Village Area to an MCL is about 3000 ft. This is for the case of DBCP. The MCL for EDB is estimated to occur at a maximum distance of approximately 2000 ft. The greater travel distance of DBCP is expected given the higher source concentration and greater degradation half-life. These distances represent 90th percentile quantities. The 50th percentile distances, for instance, which may be considered more "average estimate" distances, are about 1300 and 2000 feet, respectively, for EDB and DBCP.

- The 90th percentile travel distances for DCP and TCP are significantly smaller than for DBCP and EDB because the source concentrations in the Kunia Village Area are much closer to the MCL values for the compounds. The MCL for DCP and TCP is 5 µg/L and 0.8 µg/L, respectively, as compared to 0.04 mg/L for DBCP and EDB. As a result, the estimated travel distances for the two compounds are both less than about 100 ft.
- There is no significant difference between the results for different time periods. This suggests that steady-state conditions occur rather rapidly. For each chemical, the distances for the different time periods are similar (Table 5-7). This is to be expected considering the rapid groundwater flow velocities and steady source concentrations. In other words, after 5 to 10 years, the plume size does not change significantly. Running of the model for longer time periods, i.e., greater than 20 years, will therefore not result in significantly different results than those shown. As a result of this and because of the extremely short estimated travel distances for DCP and TCP, the model was run for only one time period (10 year) for DCP and TCP, as shown in Table 5-7 and Appendix J.
- Since all of these distances are significantly less than the distance to the HCC Well and Honouliuli wells (of about 8300 ft and 23,000 feet, respectively), these results indicate that the potential downgradient receptor wells (especially the Honouliuli wells) are not expected to be at risk of future impacts above MCLs from the currently observed Kunia Village Area groundwater chemicals.

#### 5.3.4.3 Existing Extent of Migration of Historically Observed Impacts

Additional BIOSCREEN analyses are made to estimate the existing extent of migration of historically observed EDB and DBCP impacts to the basal aquifer. For these runs, the source concentrations determined in Section 5.3.3.3.1 above, of 15 µg/L and 6.6 µg/L for EDB and DBCP, respectively, are assumed. These concentrations are then decayed using the source half-lives determined in Table 5-6 of 6 and 12 years, respectively. The model is run for 17 years to reach the present time from 1980. Historical data are not adequate for modeling of DCP and TCP.

For these runs, BIOSCREEN is run in a deterministic manner, i.e., without using the probabilistic modifications described above. The reason is that, due to programming specifics within BIOSCREEN, the program cannot be run probabilistically while assuming a decaying source.

Three sets of runs are made for each chemical: a "reasonable worst case," representing combinations of parameters expected to result in the longest travel distances, an "average case", representing combinations of parameters expected to result in the most expected travel distance, and a "reasonable best case" representing combinations of parameters expected to result in the shortest travel distance. The "reasonable worst case" and "reasonable best case" do not represent the absolute worst and best cases. The absolute worst and best cases would use combinations of parameters which, while within the theoretical range of parameter values, would be extremely unlikely to occur

all at the same time. The "reasonable worst case" and "reasonable best case" are used in lieu of these absolute, extremely unlikely cases.

The "reasonable worst case" is based on a longitudinal dispersivity of 100 ft, and solute half-lives of 15 and 40 years, respectively, for EDB and DBCP. These assumed values of longitudinal dispersivity and solute half-life maximize the travel distance. The "average case" is based on a longitudinal dispersivity of 150 ft, and solute half-lives of 10 and 20 years, respectively, for EDB and DBCP. These are considered more representative average values. The "reasonable best case" is based on a longitudinal dispersivity of 200 ft, and solute half-lives of 2 and 10 years, respectively, for EDB and DBCP. All of the runs conservatively assume a source thickness of 10 ft.

The groundwater velocity is a function of hydraulic conductivity, hydraulic gradient and porosity. Considering the ranges of possible values for these parameters and assuming most likely average values for the Pearl Harbor Basal Aquifer of about 1500 ft/day hydraulic conductivity, 1 ft per mile gradient and porosity of 0.075, results in a representative velocity of about 1500 ft/yr (See Section 3.5.2.1.3). All cases are based on a groundwater flow velocity of 1500 ft/year. Different values for groundwater velocity were not incorporated into the cases because of all the parameters, groundwater velocity is believed to be relatively well-known.

The source width is reduced from the 400 ft width assumed in the first set of model runs to account for some partial containment which is believed to have occurred due to the pumping of the Kunia Well. The pumping history of the Kunia Well, discussed in Section 3.2.1.3 and 5.3.1.5, indicates that partial or near-complete containment may have occurred throughout the period 1980 to 1994 when the well was actively pumped. Even the minimum pumping routine of about 4 to 8 hours per day twice a week (or an average rate of about 23 gpm) was significant. Capture zone analyses in Appendix H suggest that it is reasonable and conservative to assume that 23 gpm resulted in capture of approximately one-fourth or 25% of the plume. Therefore, the source width is reduced from 400 to 300 ft in this set of modeling runs. It is quite possible that during the early 1980s, when the levels of COPCs were highest in the Kunia Well, that much more than 25% containment was occurring since the pumping rates were much higher than 23 gpm during this period. Pumping rates during 1980 through 1983 are believed to have been about 3 times this rate (See Table 3-1).

For each chemical, the model is run for 17 years to obtain an estimate of the current extent of the plume from 1980. The results of these runs are shown in Table 5-8 and Figure 5-6. BIOSCREEN output for all of these runs, including the estimated concentrations with distance from the Kunia Village Area, are shown in Appendix J-2.

#### 5.3.4.4 Results of Modeling of Historically Observed Impacts

As seen in Table 5-8 and Figure 5-6, the current distance to the MCL for EDB is estimated to be approximately 4500 ft for the "reasonable worst case", 2500 ft for the "average case", and 1800 ft for the "reasonable best case". For DBCP, the current

distance to the MCL is estimated to be approximately 4500 ft for the "reasonable worst case", 2900 ft for the "average case", and 2000 ft for the "reasonable best case".

It is important to note that even though the travel distances to the MCLs are less than about 4500 ft as indicated, detectable levels of EDB and DBCP may extend beyond these distances, such as to the HCC Well and possibly to the Honouliuli wells under reasonable worst case conditions. The estimated downgradient extents of EDB and DBCP migration beyond the Kunia Village Area are shown in the model output included in Appendix J-2.

All these results indicate that the maximum anticipated travel distances, both currently and in the future, to a drinking water standard is less than about 4500 feet. This distance represents a "reasonable worst case" estimate (for the historical case). Under no scenarios, therefore, current or in the future, would any existing downgradient wells be expected to be impacted above drinking water standards based on this modeling. Since levels have been declining in the groundwater at the Kunia Village Area, and are expected to continue to do so, these distances are expected to only decline over time in the future.

Modeled results can be compared to actual data for the new Basal Well to evaluate how closely the model is predicting concentrations immediately downgradient of the Kunia Village Area. Average EDB and DBCP concentrations at the Basal Well are about 0.1 μg/L and 0.7 μg/L, respectively. The BIOSCREEN modeling predicts current concentrations of about 0.4 μg/L for both compounds at a distance of 150 ft using the average case modeling scenario. These predicted results are considered reasonably close to measured concentrations, given the uncertainties typically involved in any modeling exercise.

Table 5-9 presents a comparison of model results for the approximate location of the HCC Well vs. historical DBCP data for the HCC Well. This check is conducted for DBCP as it is the only compound ever detected at the HCC Well. This comparison is useful as a check of how similar the historical data are to predicted results. It should be emphasized that it is not certain that historical DBCP occurrences at the HCC Well are in fact related to the Kunia Village Area, since it is not known if the well is actually located along the downgradient flowpath or if the well is in the same aquifer as the Kunia Village Area groundwater. The best estimate is that the well is indeed located in the same aquifer, but there is some uncertainty in this regard. Travel time estimates suggest any DBCP impacts to the well from the Kunia Village Area should have occurred significantly prior to when they were first observed. However, there are limited data for the well during some of this period. It is quite possible that the observed DBCP at the HCC Well is from a source other than the Kunia Village Area. Given the proximity of the well to the contact with the Koolau aquifer, and the discharge of Koolau aquifer water to the Waianae aquifer, it is possible that regional DBCP occurrences in the Koolau aquifer have impacted the HCC Well.

With these items in mind, the modeled results for DBCP are listed in Table 5-9 with the historical data. The historical data shown in the table for the HCC Well reflect average

concentrations calculated from the actual data for each year, since the model can only return data at yearly intervals. As seen in the table, while there are some differences, such as in the timing of the first observed occurrences at the well, the predicted and observed DBCP concentrations do not differ greatly from each other. The model predicts current levels at the well to be approximately 0.01 to 0.02 $\mu$g/L. Recent results for the well ranged from <0.04 to 0.071 $\mu$g/L. If the observed DBCP at the well is associated with the Kunia Village Area, which is believed possible though not necessarily likely, then the model used herein is matching the observed data reasonably well given uncertainties typically involved in any modeling exercise. The similarity between the two data sets however provides reasonable assurance that the model is effectively estimating potential risks which may be posed by the Kunia Village Area.

It is also possible that impacts above the detection limit, but below the MCL, may extend to the Honouliuli wells. As seen in Appendix J-2, under the reasonable worst case scenario (for the historical case), EDB and DBCP levels fall in the range of about .01 to .02 $\mu$g/L, levels which are approximately equivalent to the detection limits for the two compounds. Under the average case scenario, however, the estimated levels for both compounds are less than 0.01 $\mu$g/L. As with the HCC Well, it is not certain, however, if these wells are located on the downgradient flow path from the Kunia Village Area. No COPCs have ever been detected at these wells. Sampling has been conducted as recently as May and July 1998.

These modeled estimates of travel distances to the MCLs are based upon conservative assumptions and calculations which included worst case scenarios. In addition to the conservative values used for transport parameters (i.e. worst case scenarios and probabilistic inputs which account for the possibility of extreme values), the modeling is based on a water table surface concentration, which ignores the fact that any downgradient production well will draw water from a relatively large screened interval. The concentration of water extracted from such an interval may exhibit a significantly lower concentration than that calculated in the modeling. Also, no downward gradients or dilution due to infiltrating surface water are assumed in the migration of COPCs from the Kunia Village Area. Infiltration of surface water and downward gradients would dilute the COPCs to lower concentrations than are predicted herein.

Also, only a relatively small amount of containment (25%) was assumed from pumping during the period 1980 to 1994. It is quite possible that, especially during the early 1980s when levels of COPCs were highest, that pumping was more significant than assumed in containing chemicals since the pumping rates were much higher than assumed. If a greater amount of containment was occurring after 1980 than was assumed, then the travel distances and downgradient concentrations (historically observed impacts) would be lower than those estimated herein.

As a result of the conservative framework of the modeling, therefore, there is confidence that the results represent a sound evaluation of the potential downgradient migration of Kunia Village Area chemicals in basal groundwater.

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As a result of the conservative framework of the modeling, therefore, there is confidence that the results represent a sound evaluation of the potential downgradient migration of Kunia Village Area chemicals in basal groundwater.

Chapter 6

# 6. SUMMARY AND CONCLUSIONS

This chapter summarizes the results and conclusions of the Del Monte Corporation (Oahu Plantation) Superfund Site RI, provides recommendations for any additional work needed to fulfill the RI objectives, discusses any modifications to the RAOs resulting from RI data, and provides recommendations for the FS.

## 6.1 Summary

### 6.1.1 Nature and Extent of Contamination

The following is a summary of chemical compounds detected above regulatory screening criteria in each of the study areas investigated as part of this RI.

**Kunia Village Area Soil Samples** - EDB, DBCP and other volatile organic compounds were not detected in Kunia Village Area shallow vadose zone soils. With the exception of one soil sample that contained total petroleum hydrocarbon compounds (TPH) in excess of Hawaii regulatory standards, there were no COPCs detected in shallow vadose zone soil samples above the EPA region IX residential PRGs. DMFP in consultation with the HDOH excavated the TPH impacted soils, collected confirmatory cleanup samples from the excavation pit, and treated the excavated soils by thermal desorption in compliance with applicable regulations. Soil gas samples collected in the vadose zone did not contain concentrations of volatile organic compounds that would exceed regulatory screening criteria in the ambient air.

**Kunia Village Area Surface Water** - Three surface water samples were collected along the flowpath of the ephemeral gulch north of the Former Fumigant Mixing and Storage Areas. EDB and DBCP were detected in one of the samples at concentrations of 170 $\mu$g/L and 0.4 $\mu$g/L, respectively. A grab sample from the excavation pit collected at approximately the same time contained similar concentrations of EDB and DBCP (167 and 0.3 $\mu$g/L, respectively). Water only flows in the gulch during heavy rainfall, and samples were collected during an unusually heavy rainfall event. During the time when the surface water samples were collected (March 1997) water within the excavation pit had risen to a historically high level due to the record rainfall during the winter of 1996-97, and appears to have been flowing into the ephemeral gulch at a point where the surface water sample which exhibited the EDB/DBCP detections was collected. This surface water sample contained similar concentrations of EDB and DBCP as was observed in the excavation pit water sample, and therefore the EDB/DBCP detections are believed to be the result of the excavation water overflow into the gulch. The other two samples collected in the ephemeral gulch did not contain detectable levels of EDB and DBCP. Bromacil and lindane were also observed in surface water samples, but at concentrations below MCLs or PRGs. DMFP has constructed an earthen berm to prevent potential future stormwater runoff from the excavation pit as an interim measure during completion of the RI/FS.

**Kunia Village Area Perched Groundwater** - Samples collected from portions of the perched groundwater system beneath the Kunia Village Area indicated the presence of ethylene dibromide (EDB), 1,2-dibromo-3-chloropropane (DBCP), 1,2-dichloropropane (DCP), 1,2,3-trichloropropane (TCP), benzene, and lindane in excess of MCLs or PRGs. The concentrations of these compounds are generally lowest in the Kunia Spill Area and the Former Fumigant Mixing Area. The highest detected concentrations are generally detected in the Former Fumigant Storage Area in the vicinity of wells MW-3 and MW-3S.

Hydropunch sampling of the perched groundwater system in these three areas indicate that concentrations of these compounds are generally highest at the base of the perched groundwater system. One exception to this is the concentrations of DBCP and DCP detected in MW-3S which is installed in the upper portions of the perched aquifer in the Former Fumigant Storage Area. The detected concentrations of DBCP and DCP in MW-3S are greater than the levels detected at the base of the perched aquifer in this area as determined by sampling MW-3. Cis- and trans- 1,3-dichloropropene were detected in Well MW-3S only during the September 1997 sampling. The detected concentrations were in excess of PRGs.

Additional soil sampling was conducted to determine locations and screened intervals for perched zone extraction wells to be used in the Phytoremediation Treatability Investigation. This sampling further defined the extent of elevated concentrations of COPCs especially EDB, DBCP, and DCP in the Former Fumigant Storage Area. As with previous investigation results, concentrations were typically highest at the base of the perched zone, with two exceptions where higher concentrations were observed at depths of 30 ft to 40 ft.

Levels of DBCP at Well MW-3S and in the Hydropunch sample collected at 33 ft depth at MW-3 exceed 1% of the DBCP solubility. This is typically regarded as indicative of the presence of NAPL (Cohen et al., 1993). Evidence of NAPL was not observed, however, in any other samples collected from the Former Fumigant Storage Area, including the soil samples collected from the nine treatability investigation boreholes drilled around the MW-3S/-3 location. This indicates the distribution of potential NAPL is confined to a relatively small area in the immediate vicinity of Well MW-3S.

**Basal Aquifer Sampling Results** - The presence of COPCs in the basal aquifer beneath the Kunia Village Area was investigated through the collection of groundwater samples from the Kunia Well and the new Basal Well (State Well #2703-02). Multiple samples have been collected from both wells and tested for the full list of preliminary COPCs assigned in the RI/FS Work Plan (ICF 1997). EDB, DBCP and TCP are the only compounds which have been detected in either well above HDOH drinking water MCLs. The concentrations of EDB and DBCP detected in the Kunia Well ranged from less than the detection limit to 0.22 $\mu$g/L and 0.7 to 1.4 $\mu$g/L, respectively. The concentrations of EDB and DBCP detected in the Basal Well ranged from 0.1 to 0.26 $\mu$g/L and 0.66 to 0.93 $\mu$g/L, respectively. The Hawaii drinking water standard for EDB and DBCP is 0.04 $\mu$g/L. The concentrations of TCP ranged from less than the detection limit

to 1.0 $\mu$g/L in the Kunia Well and non-detect to 0.8 $\mu$g/L in the Basal Well. The Hawaii drinking water standard for TCP is 0.8 $\mu$g/L.

Four regional basal wells were also included in the groundwater sampling program: the "Navy Well", Hawaii Country Club (HCC) Well, Well ST12MW05 at the Air Force Waikakalaua Fuel Storage Annex (FSA), and Honouliuli II Well 2303-03. The Navy Well is an upgradient well located approximately 1 mile north of the Kunia Village Area. The well is completed within a transitional zone between the Schofield High-level Water Body and the Pearl Harbor Basal Aquifer. TCE was detected in the Navy Well at a maximum concentration of 3.0 $\mu$g/L. The HCC Well, located approximately 1.5 miles south of the Kunia Village Area, is the nearest potentially downgradient well. While there is some uncertainty as to which aquifer the well is completed in, it is the professional judgment of the RI authors that the well is completed in the Waianae aquifer. However, even if the well is within the same aquifer as the Kunia Well/Basal Well, it may not be located on the downgradient flow path from the Kunia Village Area. DBCP was detected in the HCC Well at concentrations ranging from <0.04 to 0.071 $\mu$g/L. Low levels of DCP and TCP, at concentrations less than the quantitation limit, were detected during one round of sampling in the HCC Well. TCE was detected at a concentration of 0.5 µg/L in Well ST12MW05. The Air Force Well is located approximately 1.5 miles east of the Kunia Village Area and is believed completed within the Koolau portion of the Pearl Harbor aquifer. No COPCs were detected in the Honouliuli Well 2303-03.

**Other Potential Source Areas** - Other potential source areas identified in the RI/FS Work Plan (ICF 1997) were investigated as part of the site RI. With one exception, no COPCs were identified at any of the other potential source areas above residential PRGs or Hawaii action levels for TPH. The one exception is the presence of TPH diesel compounds detected near a former underground storage tank located at the Field 9 Booster Pump site. Soil samples collected at depths of 16 ft and 25 ft below ground surface had detected TPH concentrations in excess of the State of Hawaii Tier 1 Action Levels. DMFP has developed a Corrective Action Plan for the Field 9 Booster Pump that was implemented in September 1998.

### 6.1.2 Fate and Transport Analysis

The primary results and conclusions of the fate and transport analysis can be summarized as follows:

- Only one of the preliminary exposure pathways (which also requires fate and transport analysis) included in the SCM TM (ICF 1995b) is believed to be complete based on an evaluation of RI data results. This pathway involves the potential exposure to COPCs via groundwater in the basal aquifer. This is the only pathway, therefore, which requires a fate and transport evaluation in this RI.
- The only significant source of chemicals to the basal aquifer is area wide infiltration of impacted perched aquifer groundwater in the immediate vicinity of the Kunia Village Area. The Kunia Well, while it may have served as a

conduit for COPCs in the past, does not currently represent a significant conduit for vertical migration of chemicals to the basal aquifer and has not since about 1990. Even during the time period when the well may have served as a conduit, pumping of the well was sufficient to contain chemicals which reached the basal aquifer via this mechanism. Therefore, fate and transport modeling needs only to consider the impacts from area wide infiltration and not leakage through the Kunia Well annulus. The areal extent of the perched aquifer source to the basal aquifer can be approximated by the area enclosed within wells MW-1 through MW-6. This is an area roughly 300 ft by 300 ft in size.

- Pumping of the Kunia Well prior to the well's disconnection from the potable water supply in April 1980 is believed sufficient to have contained basal aquifer COPCs and prevented migration away from the Kunia Village Area based on capture zone analysis. Pumping after this time through 1994 may have been sufficient to limit, perhaps significantly so, downgradient migration, however it has been conservatively assumed in this RI that pumping after 1980 was not sufficient for containment. Transport modeling of impacts from historical COPC occurrences is therefore conducted for basal groundwater impacts which occurred after April 1980. A moderate and conservative reduction in the strength of the source after 1980 is included in the transport calculation reflecting continued pumping which occurred at the Kunia Well through 1994.
- The modeling is conducted for EDB and DBCP only for the historical modeling runs, and for EDB, DBCP, TCP and DCP for the predictions of future migration. These four compounds are the only compounds consistently detected in the basal aquifer at the Kunia Village Area. Historical data are not adequate to model prior occurrences of TCP and DCP.
- The thickness of basal groundwater which is impacted by chemicals infiltrating from the perched groundwater is believed to be small in relation to the screened interval of the Kunia Well. A conservative estimate suggests it does not exceed a thickness of about 1 to 10 ft near the water table surface directly beneath the perched aquifer source area.
- The Kunia Well is located within the source area of COPCs within the basal aquifer, or is extremely close to it, and capture zone analyses confirm that the well draws water primarily from the source area during sampling events. Chemical data obtained from the well can therefore be used to estimate source area concentrations for subsequent transport modeling. Since the well draws water from the entire 150 ft interval, however, and chemicals are believed restricted to the upper 1 to 10 ft, levels observed in the well during pumping need to be adjusted (upwards) to reflect the levels considered representative of the surface impacted layer. The results of the vertical profiling are believed more representative of these levels than those measured during pumping. Estimates of EDB and DBCP impacts to the basal groundwater from perched groundwater generally support the view that vertical profiling results are representative of the near water table surface source layer. EDB and DBCP levels measured during vertical profiling were 5 to 10 times and 2 to 3 times levels measured during pumping, respectively.

- Any potential receptors of chemicals migrating away from the Kunia Village Area are associated with the Waianae aquifer only, as groundwater beneath the Kunia Village Area is within the Waianae portion of the Pearl Harbor basal aquifer. Koolau aquifer wells are not at risk as they are hydraulically separated from the Waianae aquifer by the higher heads of the Koolau aquifer. This includes the Kunia I and II Wells, which are located in the Koolau aquifer. Potential downgradient receptors therefore include the HCC Well, Honouliuli I and II wells, and possibly other Waianae aquifer wells further beyond the Honouliuli wells, such as the Barber's Point Shaft. Even though the wells are believed installed in the same aquifer as the Kunia Well/Basal Well, there is uncertainty whether the HCC Well and Honouliuli wells are located along the downgradient flowpath from the Kunia Village Area.
- The first observed occurrence of DBCP at the HCC Well was in 1993, although there is limited sampling data from the HCC Well prior to 1993. Estimates of groundwater travel time from the Kunia Village Area to the HCC Well (travel time of about 5 years or less to the HCC Well 1.5 miles south of the Kunia Village Area) indicate that DBCP should have been detected at the well earlier than 1993, if it was indeed derived from the Kunia Village Area. It is therefore possible the observed DBCP impacts are not attributable to the Kunia Village Area. Other sources of DBCP are present in Central Oahu which could account for the observances at the HCC Well. However, there is a possibility that DBCP at the HCC Well is attributable to the Kunia Village Area. For instance, if Kunia Well pumping after 1980 was more effective than assumed at containing DBCP, then the travel time of DBCP to the HCC Well could have been delayed, and DBCP occurrences at the well could then be attributable to the Kunia Village Area. However, it is not certain that the HCC Well is located on the downgradient flowpath from the Kunia Village Area or is in the same aquifer. Due to these uncertainties, it is not possible to determine whether or not the observed DBCP is associated with the Kunia Village Area. If it is assumed the DBCP occurrences at the HCC Well are attributable to the Kunia Village Area, it is unlikely that these levels will increase in the future since sufficient time has passed for the peak concentrations of a potential plume to have reached the well (based on travel time estimates). Kunia Village Area concentrations have been declining historically. For the Honouliuli II wells, travel time estimates indicate that it is likely chemicals would have already reached the wells, if they were to do so, and yet no chemicals have been observed to date, including sampling conducted as recently as May and July 1998.
- The contaminant transport model, BIOSCREEN, was used to assess the potential downgradient extent of COPC migration from the Kunia Village Area in the Waianae aquifer. Modeling was conducted for the following two sets of analyses:

    1. Modeling of the current downgradient impacts (for EDB and DBCP only) due to historical (post-1980) COPC occurrences in basal groundwater, and

2. Modeling of future impacts (for EDB, DBCP, TCP, and DCP) due to the currently observed Kunia Village Area concentrations.

The modeling indicates that chemicals in basal groundwater emanating from the Kunia Village Area are strongly influenced by the naturally occurring processes of hydrodynamic dispersion and degradation. These natural attenuation processes result in significantly reduced concentrations in basal groundwater downgradient from the Kunia Village Area. The results of the first set of analyses (modeling of historical impacts) indicate that the anticipated travel distance to the EDB and DBCP MCLs to date, assuming a "reasonable worst case" scenario, is about 4500 feet from the Kunia Village Area for both compounds. Using more typical values for the various transport input parameters results in "average case" estimated travel distances to the MCL of about 2500 ft and 2900 ft, respectively. The "reasonable best case" estimated travel distances are about 1800 ft and 2000 ft, respectively. These travel distances at MCLs for EDB and DBCP are within the property boundaries beneath existing pineapple fields.

Basal aquifer impacts are predicted to extend beyond these distances, for instance to the HCC Well and possibly to the Honouliuli wells, but not at levels above drinking water standards. The model predicts, using the "reasonable average case" input parameters, current EDB and DBCP levels at the HCC Well of approximately 0.01 to 0.02 $\mu$g/L (approximately equivalent to the method detection limit of .01 $\mu$g/L for EDB and .02 $\mu$g/L for DBCP). This assumes the HCC Well is located along the downgradient flow path from the Kunia Village Area which is not certain. Recent DBCP analytical results for the HCC Well ranged from <0.04 to 0.071 $\mu$g/L. If the observed DBCP at the well is associated with the Kunia Village Area, which is believed possible though not necessarily likely, then the model used herein is matching the observed data reasonably well. The model predicts declines in DBCP concentrations in the vicinity of the HCC Well in the future if the source area declines continue. EDB was not detected at the well during RI sampling activities.

It is also possible that impacts above the detection limit, but below the MCL, may extend to the Honouliuli wells. Under the reasonable worst case scenario, EDB and DBCP levels fall in the range of about .01 to .02 $\mu$g/L, levels which are approximately equivalent to the detection limits for the two compounds. Under the average case scenario, however, the estimated levels for both compounds are less than 0.01 $\mu$g/L. As with the HCC Well, it is not certain, however, if these wells are located on the downgradient flow path from the Kunia Village Area. No COPCs have ever been detected at these wells.

Modeling of the future impacts (for EDB, DBCP, TCP and DCP) from present-day concentrations (which conservatively assumed constant source area concentrations into the future) was performed using a modified approach to that used above which allowed for the use of probabilistic inputs to BIOSCREEN. Probability distribution functions (PDFs) were used for many of the transport

input parameters. This allowed for the calculation of ranges of possible travel distances resulting from the various inputs. The results of the modeling indicated that the maximum future estimated travel distance from the Kunia Village Area to an MCL is about 3000 ft. This is for the case of DBCP. The MCL for EDB is estimated to occur at a maximum distance of approximately 2000 ft. These distances represent 90th percentile quantities (90% of the results were less than or equal to this distance). 95% UCL mean values were also calculated, but this resulted in a shorter travel distance than the 90$^{th}$ percentile distances. The 50th percentile distances, which may be considered more "average estimate" distances, are about 1300 and 2000 feet, respectively, for EDB and DBCP. Estimated travel distances to the DCP and TCP MCLs are much shorter than for EDB and DBCP (less than about 100 ft). These estimated travel distances are much smaller than the EDB and DBCP travel distances due to the fact that the Kunia Village Area DCP/TCP groundwater concentrations are only very marginally in excess of the MCLs for these two compounds. These modeling results indicate therefore that there is little likelihood of future impacts to any existing downgradient wells at levels above MCLs even if current concentrations remain constant in the Kunia Village Area. All travel distances to MCLs are within the property boundaries beneath existing pineapple fields.

The estimates of travel distances are based upon conservative assumptions and calculations which included reasonable worst case scenarios and, therefore, likely overestimate actual conditions. In addition to the conservative values used for transport parameters, the modeling is based on a water table surface concentration, which ignores typical well construction practices on Oahu. Any downgradient production well will draw water from a large screened interval. The concentration of water extracted from such an interval may exhibit a significantly lower average concentration than that calculated for the water table surface in the modeling. Also, no downward gradients or dilution due to infiltrating rain water were assumed in the migration of COPCs from the Kunia Village Area. Infiltration of rain water and downward gradients would dilute the COPCs to lower concentrations than are predicted herein.

In addition, only a relatively small amount of containment (25%) was assumed from pumping during the period 1980 to 1994. 25% containment was assumed based on a pumping rate of 23 gpm, which is equivalent to pumping about 6 hours per day twice per week. During the early 1980s, when levels of COPCs were highest in the Kunia Well, pumping was considerably greater than 23 gpm. If a greater amount of containment was occurring after 1980 than was assumed, then the travel distances and downgradient concentrations (historically observed impacts) would be lower than those estimated herein.

### 6.1.3 NPL Site Boundaries

The National Priorities List (NPL) of CERCLA does not describe releases in precise geographical terms. The Del Monte Corporation (Oahu Plantation) Superfund Site is typical of many large facilities where large tracts of land have been included by association with the NPL Site Name as part of the Site although they pose no significant

threat to human health or the environment. EPA regulations provide that the nature and extent of the threat presented by a release will be determined by the Remedial Investigation/Feasibility Study as more information is developed on Site contamination.

Based on the results of this RI, the site boundaries of the DMC NPL Site can be described in general geographical terms as the known source areas at the Kunia Village Area and the potential downgradient (or south-southwest) travel distances at or above Maximum Contaminant Levels of Chemicals of Potential Concern in the Waianae portion of the Pearl Harbor Aquifer within the existing property boundaries of the Kunia section of the Oahu Plantation.

DMFP has requested that EPA more accurately define the NPL Site boundaries as described above. This request is currently under consideration by EPA.

## 6.2 Conclusions

### 6.2.1 Recommendations for Further Work

The overall goal of the RI investigations and data evaluation/analysis activities was to define the nature and extent of contamination in soils and groundwater at the known and suspected source areas to support an assessment of potential risks to human health and the environment (to be conducted in the BRA), and to evaluate and select remedial options, if needed, for mitigating any unacceptable risks (to be conducted in the FS).

The nature and extent of contamination has been adequately defined to meet these goals, as discussed below:

- Shallow soil COPC occurrences were found to be very limited, and consisted only of TPH impacts observed in two samples. The detected impacted soil at one of these locations has been removed already, and the other location will be addressed in the context of a separate regulatory program (Hawaii DOH UST regulations).
- Surface water impacts were found to be limited as well. No interaction between perched groundwater and surface water is believed to occur. Impacts to surface water are limited to pit water in the Kunia Village Area. Only during extreme rainfall events, when the pit overflowed to surface water in the ephemeral gulch, was there a possible release of COPCs to a surface water course. The travel distance from Kunia Village Area to Waikele Stream, which is through previous pineapple fields and normally dry gulches, is approximately 2.5 miles. As discussed in Section 4.2.3, however, additional sampling will be conducted in the ephemeral gulch to confirm that the prior COPC release was due to pit overflow.
- No soil gas samples contained COPCs at levels which would result in the exceedance of ambient air screening values.

- Perched groundwater (and associated deep soils) and basal groundwater do contain COPCs at levels above regulatory screening criteria, which will require assessment in the BRA and FS. The extent of these impacts has been adequately defined however. Perched groundwater impacts are limited to the vicinity of wells MW-1 through MW-6. The most significant impacts are near wells MW-3 and MW-3S in the Former Fumigant Storage Area. The impacts of the perched groundwater COPCs to the basal aquifer have been estimated and found to be similar to measured values (vertical profiling results) believed representative of the impacted basal groundwater. The nature and extent of basal aquifer impacts has been determined through groundwater modeling analysis. The results of this modeling are sufficient to determine location specific exposure concentrations in the BRA.

The nature and extent of contamination has been adequately defined to support the completion of the BRA and FS, and therefore, no new major data collection activities are believed necessary.

### 6.2.2 Recommended Remedial Action Objectives (RAOs)

The Remedial Action Objectives (RAOs) for this project were originally defined in the Work Plan (ICF 1997) and included specific goals regarding prevention of exposure and acceptable carcinogenic and non-carcinogenic risks. RAOs were defined for the following environmental media:

- Groundwater (Perched and Basal);
- Soil (Shallow - less than 5 ft bgs);
- Soils (Deep - greater than 5 ft bgs); and
- Surface Water.

Exposure to COPCs via ingestion, inhalation and dermal contact were the relevant exposure mechanisms for groundwater, surface water and shallow soils. For deep soils, the exposure pathway was defined to include leaching of chemicals to perched and basal groundwater.

Based on the RI data collected to date, it is appropriate to re-evaluate these RAOs to determine if they are adequate to address potential risks posed:

- As discussed in Chapter 4, only one shallow soil sample (above 5 ft depth) collected in the Kunia Village Area contained a COPC (TPH) in excess of screening levels. The impacted soils were excavated and thermally treated, as discussed in Section 4.2.1. Only one other sample collected during the RI contained a COPC above screening levels, and this sample also contained TPH. TPH impacts have been addressed within the context of Hawaii UST regulations. Also, as discussed in Chapter 4, no COPCs were observed in soil gas at levels which would be expected to be of concern in ambient air, using a conservative calculation approach. Due to the lack of shallow soil or soil gas COPCs in excess

of regulatory screening criteria anywhere on the Oahu Plantation, the shallow soils pathway (involving ingestion, inhalation and leaching) does not include complete exposure pathways. It is therefore appropriate to eliminate RAOs which address shallow soils.

- Groundwater (perched aquifer and basal aquifer) and deep soil media do represent potentially complete exposure pathways. However, in the Work Plan (ICF 1997), no differentiation is made between perched groundwater and basal groundwater with respect to RAOs. Perched groundwater is not used as a drinking water source, although it does discharge to the basal groundwater which is used for drinking water purposes. Nor does perched groundwater, apart from the excavation pit, have any interaction with surface water. Therefore, it is not appropriate for the RAOs for perched and basal groundwater to be the same. Perched groundwater and deep soils are significant only in their potential for impacting basal groundwater.
- In the Work Plan (ICF 1997), RAOs for surface water address the ingestion pathway and refer to surface water quality standards (Clean Water Act criteria). However, the RI has demonstrated that the only impacted surface water is represented by the water occasionally found in the excavation pit. This water is not used as a drinking water source and ingestion is therefore not a reasonable exposure pathway to be assumed. Nor are surface water criteria applicable to this water since the ephemeral pit does not support aquatic life. The relevant exposure pathway for pit water is inhalation and not ingestion.
- RAOs presented in the Work Plan do not address potential ecological receptors. However, the RI results have indicated that shallow soils, and surface water in the ephemeral gulch are not impacted by COPCs. In addition, the ephemeral pit does not support aquatic life. Chemical impacts associated with the Kunia Village Area are not accessible to potential ecological receptors. Therefore, a complete pathway for ecological exposure does not exist, and it is not necessary to designate RAOs related to ecological impacts. Nor is an ecological risk assessment needed.

Therefore, based on the above and the preliminary RAOs outlined in the Work Plan, recommended RAOs include the following:

Basal Groundwater

- Prevent ingestion (or inhalation) of water having contaminants over their respective MCLs, or a contaminant specific excess carcinogenic risk greater than one in a million, or a non-carcinogenic hazard index greater than one.
- Prevent ingestion (or inhalation) of water having contaminants with an excess carcinogenic risk for all contaminants greater than one in ten thousand, or a total non-carcinogenic hazard index greater than one.

Perched Groundwater (including Deep Soils)

- Limit discharge of perched groundwater to basal groundwater such that the basal groundwater RAOs are achieved.

Surface Water (excavation pit area only)

- Prevent inhalation of contaminants in water with chemical concentrations in excess of a contaminant specific excess carcinogenic risk greater than one in a million, or a non-carcinogenic hazard index greater than one.
- Prevent inhalation of contaminants in water with chemical concentrations in excess of a carcinogenic risk for all contaminants greater than one in ten thousand, or a total non-carcinogenic hazard index greater than one.

### 6.2.3 Recommendations for the Feasibility Study

The initial steps of the FS were conducted in the Work Plan (ICF 1997). These included the following:

- Establishment of RAOs for chemicals and media of interest; and
- Identification of the applicable general response actions (e.g., containment, removal, and treatment).

From the applicable response actions, potentially applicable remediation technologies were identified and screened to obtain a set of feasible technologies for use in achieving the RAOs. Alternatives screening in the Work Plan resulted in the determination of a set of preliminary remediation alternatives for soil, and for groundwater, which were retained for further evaluation in the FS. For soils, retained alternatives included:

- No Action;
- Access Restrictions (Institutional controls);
- Containment (e.g., capping - either horizontal, vertical, or both);
- In-situ soil vapor extraction (with or without containment); and
- Ex-situ thermal desorption (presumes excavation).

For groundwater, retained alternatives included:

- No Action;
- Access Restrictions (Institutional Controls);
- Natural Attenuation (with monitoring);
- Hydraulic containment;
- In-situ biological (oxygen enhancement with either peroxide or air sparging);
- In-situ physical/chemical (air sparging); and
- Extraction with ex-situ physical/chemical treatment (air stripping, carbon adsorption, and UV oxidation).

It is appropriate to review the results of the alternative screening conducted in the Work Plan to determine whether it is appropriate at this time to add or remove some alternatives on the basis of RI results and any changes made above to RAOs.

For groundwater, the Work Plan (ICF 1997) eliminated ex-situ biological treatment as a potential technology for the treatment of extracted groundwater. Mink and Yuen, Inc. and DMFP have been pursuing the performance of a treatability investigation to assess the feasibility of using phytoremediation as a means of treating impacted perched groundwater which could be generated via groundwater extraction. The technology involves the application of chemical-containing water to phytoremediation crops in self-contained lined treatment systems. Details of the planned treatability investigation are outlined in TI Technical Memorandum 98-2 (DMFP/Mink and Yuen, 1998).

In addition, it is believed appropriate to include containment (via capping or regrading) as an alternative for perched groundwater. Surface water infiltration through the perched aquifer is the primary source of chemicals to the basal aquifer. In addition, runoff currently collects in the pit area and results in the creation of ponded water during heavy rainfall, which may result in surface water exposures. Pit water can overflow into the ephemeral gulch during extreme rainfall events. Given these factors, it is believed appropriate to include capping/regrading as a means of controlling exposure to surface water contained in the excavation pit and limiting infiltration through the perched aquifer to the basal water table.

Therefore, proposed changes to the alternatives screening conducted in the FS include:

- The addition of two new alternatives for groundwater: ex-situ biological treatment via phytoremediation to be used in conjunction with groundwater extraction, and capping/regrading to limit infiltration and control potential surface water exposures.

# Chapter 7

Tables

## 7. REFERENCES

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# TABLES

TABLE 1-1

REMEDIAL ACTION OBJECTIVES
PRESENTED IN THE WORK PLAN

**Groundwater (Perched and Basal)**

- Prevent ingestion of water having contaminants over their respective MCLs, or a contaminant specific excess carcinogenic risk greater than one in a thousand, or a non-carcinogenic hazard index of greater than one.
- Prevent ingestion of water having contaminants with an excess carcinogenic risk for all contaminants greater than one in a million, or a total non-carcinogenic hazard index greater than one.

**Soil (Shallow-less than 5 feet bgs)**

- Prevent ingestion of soils having contaminants with a contaminant specific excess carcinogenic risk greater than one in ten thousand, or a non-carcinogenic hazard index of greater than one.
- Prevent ingestion of soil having contaminants with an excess carcinogenic risk for all contaminants greater than one in a million, or a total non-carcinogenic hazard index greater than one.
- Prevent inhalation of contaminants from soil with a contaminant specific excess carcinogenic risk greater than one in ten thousand, or a non-carcinogenic hazard index greater than one.
- Prevent inhalation of contaminants from soil with an excess carcinogenic risk for all contaminants greater than one in a million, or a total non-carcinogenic hazard index greater than one.

**Soil (Deep-greater than five feet bgs)**

- Prevent leaching of contaminants to perched and basal groundwater aquifers that would lead to exceedance of any respective MCL, or exceedance of a total carcinogenic risk of one in a million or exceedance of a non-carcinogenic hazard index of one.

**Surface Water**

- Prevent ingestion of water with contaminants in excess of surface water quality standards, or a contaminant specific excess carcinogenic risk greater than one in ten thousand, or a non-carcinogenic hazard index of greater than one.
- Prevent ingestion of water having contaminants with an excess carcinogenic risk for all contaminants greater than one in a million, or a total non-carcinogenic hazard index greater than one.

PIEZOMETER CONSTRUCTION DETAILS
DEL MONTE CORPORATION (OAHU PLANTATION) SUPERFUND SITE

| Piezometer | Date Installed | Date Sampled | Borehole Depth feet bgs | Borehole Diameter Inches | Bottom of Well feet bgs | Top of Screen feet bgs | Top of Sand Pack feet bgs | Top of Bent. Seal feet bgs | Stickup of Casing feet ags | Elevation of top of 1-inch PVC (ft amsl) |
|---|---|---|---|---|---|---|---|---|---|---|
| P-1 | 3/17/93 | 3/24/93 | 46 | 3 | 46 | 26 | 23 | 19 | 2.8 | 851.33 |
| P-2 | 3/10/93 | 3/24/93 | 45 | 2 | 45 | 35 | 32 | 29 | 2.5 | 847.17 |
| P-3 | 3/18/93 | 3/24/93 | 45 | 3 | 45 | 25 | 21 | 18 | 2.45 | 847.66 |
| P-4 | 3/17/93 | 3/24/93 | 45 | 3 | 45 | 25 | 22 | 19 | 2.8 | 848.80 |
| P-5 | 3/20/93 | 3/24/93 | 35.4 | 3 | 35.4 | 15.4 | 12 | 9 | 2.6 | 831.61 |
| P-6 | 4/8/93 | 4/13/93 | 31 | 3 | 31 | 11 | 8 | 5 | 2.5 | 822.72 |
| P-7 | 4/8/93 | 4/13/93 | 30 | 3 | 30 | 10 | 7 | 4 | 2.5 | 822.32 |
| P-8 | 4/9/93 | 4/13/93 | 41 | 3 | 41 | 21 | 18 | 15 | 2.5 | 821.62 |

All piezometers are 1-inch diameter schedule 80 PVC. Well screens are schedule 80 PVC with 0.010 inch slots.
bgs - Below Ground Surface
ags - Above Ground Surface
amsl- Above Mean Sea Level

SUMMARY OF SAMPLES COLLECTED DURING PERCHED MONITORING WELL DRILLING

| Monitoring Well | Sample Depth(s) feet bgs | Media | Sampling Method | Analyses Performed |
|---|---|---|---|---|
| MW-1 | 2, 4, 10, 28, & 36 | Soil | Split Spoon | Physical Parameters |
| MW-1 | 26, 26 & 69 | Water | Hydropunch | 8260 & 504 |
| MW-1 | 71 | Soil | Shelby Tube | Physical Parameters |
| MW-1 | 82 - 92 | Water | Bailor | 8260 & 504 |
| MW-2 | 3, 5, 10, 25, & 34[a] | Soil | Split Spoon | Physical Parameters |
| MW-2 | 20, 40, & 62 | Water | Hydropunch | 8260 & 504 |
| MW-2 | 34, 51, & 68 | Soil | Shelby Tube | Physical Parameters |
| MW-2 | 68 - 78 | Water | Bailor | 8260 & 504 |
| MW-3 | 3, 5, 10, 25 & 36[a] | Soil | Split Spoon | Physical Parameters |
| MW-3 | 18, 33, & 52 | Water | Hydropunch | 8260 & 504 |
| MW-3 | 36, 48, & 56 | Soil | Shelby Tube | Physical Parameters |
| MW-3 | 62 - 72 | Water | Bailor | 8260 & 504 |

[a]Sample was co-located with Shelby tube sample
8260 - Volatile Organic Compounds
504 - EDB and DBCP
Physical Parameters - Specific gravity, organic matter content, grain size including hydrometer, porosity, and water content (for Split Spoon Samples)
Physical Parameters for Shelby Tubes - Vertical Permeability and organic matter content

PERCHED MONITORING WELL CONSTRUCTION SUMMARY
DEL MONTE CORPORATION (OAHU PLANTATION) SUPERFUND SITE

| Monitoring Well | Date Installed | Borehole Depth feet bgs | Borehole Diameter Inches | Bottom of Well feet bgs | Screen Interval feet bgs | Sand pack Interval feet bgs | Top of Bent. Seal feet bgs | Stickup of PVC Casing feet ags | Elevation of top of 2-inch PVC (ft amsl) |
|---|---|---|---|---|---|---|---|---|---|
| MW-1 | 5/13/97 | 107[a] | 8-inch | 92.2 | 81.8 - 91.8 | 79 - 92.2 | 77 | 3.0 | 846.45 |
| MW-2 | 5/19/97 | 79 | 8-inch | 79.1 | 68.7 - 78.7 | 66 - 79 | 63 | 2.6 | 823.02 |
| MW-3 | 5/29/97 | 85[b] | 8-inch | 72.4 | 62 - 72 | 59 - 74 | 49 | 2.8 | 821.74 |
| MW-3S | 8/27/97 | 40.5 | 8-inch | 40.4 | 30 - 40 | 27 - 40.4 | 23.5 | 3.0 | 821.32 |
| MW-5 | 9/5/97 | 71 | 10-inch | 70.4 | 60 - 70 | 57 - 70 | 32 | 2.8 | 819.14 |
| MW-6 | 10/23/97 | 87 | 10-inch | 78.4 | 68 - 78 | 50 - 78 | 3 | 3.0 | 817.10 |

All monitoring wells are constructed of 2-inch diameter PVC casing and 2-inch diameter prepacked screen.
The Prepacked screen has an O.D. of 3.5 inches and a slot size of 0.01"
The sandpack consist of Monterey #3 size sand
The bentonite seal on MW-1 and MW-2 is bentonite pellets; MW-3 seal is a bentonite slurry
The annulus seal for all three wells is a Portland cement/bentonite grout
[a]Borehole MW-1 sloughed in to 103 feet. A cement/bentonite grout seal was placed from 103 to 92 feet bgs.
[b]A bentonite seal was placed in MW-3 from 74 to 85 feet bgs prior to constructing the well.

TABLE 2-4

SUMMARY OF KUNIA WELL PURGING PRIOR TO VERTICAL PROFILING

| Time[a] | Meter, gals | Total Purge Quantity, gals | pH | EC, mS/cm | Turbidity, NTUs | Comments |
|---|---|---|---|---|---|---|
| 0940 | 35217100 | | | | | initial meter reading |
| 1159 | 35217600 | 0 | | | | start purging after several trial starts, begin to close valve |
| 1204 | 35217810 | 210 | | | | |
| 1208 | 35218150 | 550 | | | | |
| 1213 | 35218600 | 1000 | | | | 1st sample;DM00040[b] |
| 1215 | 35218800 | 1200 | | | | pumping at constant rate |
| 1216 | | | 5.62 | .21 | 68 | |
| 1219 | 35219150 | 1550 | | | | |
| 1221 | 35219320 | 1720 | 6.14 | .21 | 74 | |
| 1225 | 35219660 | 2060 | | | | |
| 1227 | 35219810 | 2210 | | | | |
| 1228 | | | 6.44 | .21 | 42 | |
| 1234 | 35220030 | 2430 | | | | |
| 1238 | | | | | | pump stopped due to back-pressure |
| 1239 | | | | | | start pump again, meter no longer functional[c] |
| 1307 | | | 6.71 | .23 | 20 | |
| 1309 | | | 6.72 | .23 | 15 | |
| 1311 | | | | | 15 | |
| 1314 | | | | | | 2nd sample;DM00041[b] |
| 1317 | | ~7500 | | | | Final purge quantity based on tank measurements |

[a]Purging conducted March 12, 1997.
[b]Samples analysed for EDB/DBCP only per EPA Method 504.
[c]Meter became plugged with rusty debris.

TABLE 2-5

SUMMARY OF VERTICAL PROFILE SAMPLING OF THE KUNIA WELL

| Number | Sample Tracking No. | Depth | Date | Time | Analyses | Comments |
|---|---|---|---|---|---|---|
| 1 | DM0067 | 827 | 3-15-97 | 1230-1800 | Full COPC | Clear |
| 2 | DM0068 | 837 | 3-16-97 | 0830 | 504/8260 | Clear |
| 3 | DM0069 | 847 | 3-16-97 | 0845 | 504/8260 | Clear |
| 4 | DM0070 | 857 | 3-16-97 | 0905 | 504/8260 | Clear |
| 5 | DM0071 | 867 | 3-16-97 | 0930 | 504/8260 | Clear |
| 6 | DM0072 | 877 | 3-16-97 | 0950 | 504/8260 | Clear |
| 7 | DM0073 | 887 | 3-16-97 | 1020 | 504/8260 | Clear |
| 8 | DM0074 | 897 | 3-16-97 | 1040 | 504/8260 | Clear |
| 9 | DM0075 | 907 | 3-16-97 | 1100 | 504/8260 | Clear |
| 10 | DM0076 | 917 | 3-16-97 | 1120 | 504/8260 | Clear |
| 11 | DM0077 | 927 | 3-16-97 | 1135 | 504/8260 | Clear |
| 12 | DM0078 | 937 | 3-16-97 | 1205 | 504/8260 | Slightly Cloudy |
| 13 | DM0079 | 947 | 3-16-97 | 1230 | 504/8260 | Clear |
| 14 | DM0080 | 957 | 3-16-97 | 1250 | 504/8260 | Clear |
| 15 | DM0081 | 967 | 3-16-97 | 1310 | 504/8260 | Cloudy |

TABLE 2-6

DOWNGRADIENT BASAL WELL (STATE WELL NO. 2703-02)
BOREHOLE DIAMETERS

| Interval [ft BGS] | Borehole Diameter [in.] | Comments |
|---|---|---|
| 0 to 10.2 | 20.0 | Backfilled excavation around casing |
| 10.2 to 202.8 | 17.5 | Drilled with a 17.5 inch tricone bit |
| 202.8 to 993.5 | 13.0 | Drilled with a 12.25 inch tricone bit but survey showed borehole diameter at least 13 " |

TABLE 2-7

DOWNGRADIENT BASAL WELL (STATE WELL NO. 2703-02)
CASING AND SCREEN DETAILS

| Type | Interval [ft BGS] | I.D. [in.] | O.D. [in.] | Specifications |
|---|---|---|---|---|
| Conductor Casing | 0 - 10.2 | 19.000 | 20.000 | Carbon Steel |
| Surface Casing | 0 - 202.8 | 13.250 | 14.000 | Welded Carbon Steel |
| Well Casing | 0 - 820.6 | 8.000 | 8.625 | ASTM-606-75 Type 4 Corten Steel Casing w/ stainless steel welds |
| Screen | 820.6 - 971.1 | 8.375 | 8.625 | Stainless Steel Type 304 with 3/16" openings and 29.2 $in^2$ of openings per linear foot with stainless steel welds |

TABLE 2-8

DOWNGRADIENT BASAL WELL (STATE WELL NO. 2703-02)
SUMMARY OF ANNULAR MATERIAL

| Type | Interval [ft BGS] | Outer Wall | Inner Wall | Quantity [gallons] |
|---|---|---|---|---|
| Powdered Bentonite | 9.2 to 10.2 | 21" borehole | 20" casing | 5 |
| Neat Cement w/3-5 % Bentonite | 0 to 202.8 | 0-10.2 ft - 20" casing; 10.2 -202.8 - 17.5" borehole | 14" casing | 2900 |
| 1:1 Cement to Sand Grout | 0 to 600.1 | 0 - 202.8 - 13.25" casing; 202.8 - 600.1 - 13" borehole | 8.6" casing | 4850 |
| Neat Cement w/3-5 % Bentonite | 600.1 to 796.7 | 13" borehole | 8.6" casing | 2600 |
| Bentonite Chips | 796.7 to 806.7 | 13" borehole | 8.6" casing | 150 |
| Fine Sand | 806.7 to 810.2 | 13" borehole | 8.6" casing | 40 |
| 3/8" Basalt Chips | 810.2 to 841.9 | 13" borehole | 8.6" casing | 600 |
| 3/8" Gravel | 841.9 to 971.1 | 13" borehole | 8.6" casing | 1120 |
| 3/8" Basalt Chips | 971.1 to 993.5 | 13" borehole | N/A | 200 |

TABLE 2-9

STATUS OF BASAL GROUNDWATER SAMPLING ACTIVITIES

| Well | 1st Monthly Sampling | 2nd Monthly Sampling | 3rd Monthly/ 1st Quarter Sampling | 2nd Quarter Sampling | 3rd Quarter Sampling | 4th Quarter Sampling |
|---|---|---|---|---|---|---|
| Kunia Well | Oct-97[a] | Nov-97[b] | Dec-97 | Jan-98 | May-98 | Jul-98 |
| Basal Well | Oct-97 | Nov-97 | Dec-97 | Jan-98 | May-98 | Jul-98 |
| "Navy Well" | NA | NA | Oct-97 | Jan-98 | May-98 | Jul-98 |
| HI Country Club Well | NA | NA | Nov-97 | Feb-98 | May-98 | Jul-98 |
| Waikakalaua FSA (MW-05) | NA | NA | Feb-98 | NA | NA | NA |
| Honouliuli II Well (2303-03) | NA | NA | NA | NA | May-98 | Jul-98 |

Oct-97 - Date Sampling Completed.
NA - Sampling not applicable.
[a] Sample collected at end of basal aquifer pumping test.
[b] In addition to the monthly sampling conducted on November 24, 1997, samples were also collected at intervals of 30 min., 4 hrs., 24 hrs., and 48 hrs. after start of pumping over a 2-day period November 14-16, 1997.

# HISTORICAL KUNIA WELL PUMPAGE DATA

| Year | Gallons Pumped[1] | Equivalent Pumping | |
|---|---|---|---|
| | | hrs/week[2] | gpm[3] |
| prior to 4/80[4] | | | |
| 1980 | 30000000 | 30 | 57 |
| 1981 | 32448000 | 32 | 62 |
| 1982 | 32448000 | 32 | 62 |
| 1983 | 9994000 | 10 | 19 |
| 1984 | 16224000 | 16 | 31 |
| 1985 | 16224000 | 16 | 31 |
| 1986 | 5618900 | 6 | 11 |
| 1987 | 12140500 | 12 | 23 |
| 1988 | 17904800 | 18 | 34 |
| 1989 | 14406900 | 14 | 27 |
| 1990 | 15150770 | 15 | 29 |
| 1991 | 12065480 | 12 | 23 |
| 1992 | 12065480 | 12 | 23 |
| 1993 | 24165700 | 24 | 46 |
| 1994 | 5542500 | 5 | 11 |

[1] Based on information provided by DMFP (DMFP 1998g).
[2] Number of hours pumping per week required to attain the indicated yearly totals, assuming pumping at 325 gpm.
[3] Assuming continuous pumping at 325 gpm.
[4] Prior to April 1980, the well was pumped on the order of 250,000 gallons/day. This corresponds to approximately 90 hrs/week, or an equivalent continuous rate of 175 gpm.

TABLE 3-2

SUMMARY OF AVERAGE EDB/DBCP CONCENTRATIONS AT BEGINNING AND END OF PUMPING FOR THE KUNIA WELL

| Year | Average Beginning of Pumping EDB, μg/L[a] | Average Beginning of Pumping DBCP, μg/L[a] | Average End of Pumping EDB, μg/L[b] | Average End of Pumping DBCP, μg/L[b] | Ratio of Beginning/End of Pumping EDB | Ratio of Beginning/End of Pumping DBCP |
|---|---|---|---|---|---|---|
| 1980 | 51.62 | 5.06 | 1.42 | 1.03 | 36.3 | 4.9 |
| 1981 | | | | | | |
| 1982 | 2.23 | 3.00 | 0.75 | 1.80 | 3.0 | 1.7 |
| 1983 | 3.80 | 3.04 | 1.95 | 2.26 | 1.9 | 1.3 |
| 1984 | 2.69 | 1.16 | 0.25 | 1.51 | 10.6 | 0.8 |
| 1985 | 0.79 | 1.18 | 0.39 | 1.22 | 2.0 | 1.0 |
| 1986 | 0.54 | 0.97 | 0.30 | 1.36 | 1.8 | 0.7 |
| 1987 | 0.42 | 0.54 | 0.46 | 0.93 | 0.9 | 0.6 |
| 1988 | 0.41 | 0.58 | 0.28 | 0.56 | 1.5 | 1.0 |
| 1989 | 0.42 | 1.00 | 0.26 | 0.99 | 1.6 | 1.0 |
| 1990 | 0.94 | 1.43 | 0.20 | 1.26 | 4.8 | 1.1 |
| 1991 | 0.25 | 1.26 | 0.20 | 1.54 | 1.3 | 0.8 |
| 1992 | 0.56 | 0.73 | 0.38 | 0.74 | 1.4 | 1.0 |
| 1993 | 0.28 | 0.94 | 0.33 | 0.89 | 0.9 | 1.1 |
| 1994 | 0.13 | 0.46 | 0.14 | 0.74 | 0.9 | 0.6 |
| | | | | | | |

[a] From Table G-2.
[b] From Table G-3.

EDB, DBCP AND TCP DATA SUMMARY FOR KUNIA I AND II WELLS, HONOULIULI I AND II WELLS AND HAWAII COUNTRY CLUB WELL

**KUNIA I WELLS[1]**
**EDB AND DBCP DATA SINCE 1991**

| Date | Pump 1 | | Pump 2 | | Pump 3 | | Pump 4 | |
|---|---|---|---|---|---|---|---|---|
| | EDB (ug/l) | DBCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | EDB (ug/l) | DBCP (ug/l) |
| 11/10/97 | | | <0.01 | <0.02 | <0.01 | <0.02 | <0.01 | <0.02 |
| 8/12/97 | <0.01 | <0.02 | | | | | | |
| 7/23/97 | | | | | <0.01 | <0.02 | <0.01 | <0.02 |
| 5/21/97 | | | | | <0.01 | <0.02 | | |
| 4/17/97 | <0.01 | <0.02 | | | | | | |
| 4/16/97 | | | <0.01 | <0.02 | | | <0.01 | <0.02 |
| 4/1/97 | <0.01 | <0.02 | | | | | | |
| 3/12/97 | | | | | | | <0.01 | <0.02 |
| 3/3/97 | | | <0.01 | <0.02 | | | | |
| 10/30/96 | | | | | <0.01 | <0.02 | | |
| 10/17/96 | <0.01 | <0.02 | | | | | <0.01 | <0.02 |
| 7/30/96 | | | <0.01 | <0.02 | <0.01 | <0.02 | | |
| 7/3/96 | | | | | | | <0.01 | <0.02 |
| 6/25/96 | <0.01 | <0.02 | <0.01 | <0.02 | | | | |
| 1/23/96 | <0.01 | <0.02 | | | <0.01 | <0.02 | | |
| 1/18/96 | | | | | | | <0.01 | <0.02 |
| 10/11/95 | <0.01 | <0.02 | | | <0.01 | <0.02 | | |
| 10/10/95 | | | <0.01 | <0.02 | | | | |
| 2/23/95 | <0.01 | <0.02 | | | <0.01 | <0.02 | | |
| 10/22/91 | | | <0.02 | <0.02 | | | | |
| 9/4/91 | | | | | <0.02 | <0.02 | <0.02 | <0.02 |
| 4/24/91 | | | <0.02 | <0.02 | | | | |
| 1/22/91 | <0.02 | <0.02 | | | <0.02 | <0.02 | | |

**KUNIA II WELLS**
**EDB, DBCP AND TCP LEVELS SINCE 1990**

| Date | Pump 1 | | | Pump 2 | | | Pump 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) |
| 11/24/97 | | | | <0.01 | <0.04 NQ | 0.6 | | | |
| 11/13/97 | <0.01 | <0.04 NQ | 1.0 | | | | | | |
| 8/12/97 | <0.01 | <0.04 NQ | 0.9 | | | | | | |
| 3/12/97 | | | 0.9 | | | | | | |
| 7/31/97 | | | | | | | <0.01 | <0.04 NQ | |
| 5/22/97 | | | | | | | <0.01 | <0.04 NQ | |
| 3/12/97 | <0.01 | <0.04 NQ | | | | | | | |
| 3/4/97 | | | | | | | <0.01 | <0.02 | 0.8 |
| 10/18/96 | <0.01 | <0.04 NQ | 0.9 | | | | | | |
| 8/5/96 | | | | | | | | | 1.0 |
| 8/1/96 | | | | | | | | | 1.0 |
| 7/29/96 | | | | | | | <0.01 | <0.04 NQ | 1.0 |
| 6/25/96 | | | | | | | <0.01 | <0.02 | |
| 5/31/96 | <0.01 | <0.02 | | | | | | | |
| 1/18/96 | | | | | | | <0.01 | <0.04 NQ | |
| 1/9/96 | | | | | | | | | 0.6 |
| 10/24/95 | | | | | | | <0.01 | <0.02 | |
| 10/11/95 | | | | <0.01 | <0.04 NQ | | | | |
| 5/15/95 | | | | | | <0.5 NQ | | | |
| 4/27/95 | | | | | | | | | 0.6 |
| 3/15/95 | | | | | | | <0.01 | <0.04 NQ | |
| 3/8/95 | | | | <0.01 | <0.02 | | | | |
| 2/10/95 | | | | <0.01 | <0.02 | | | | |
| 1/23/95 | | | | | | 0.8 | | | |
| 1/13/95 | | | | | | | <0.01 | <0.02 | 0.7 |
| 10/11/94 | | | | <0.01 | <0.02 | 0.5 | | | |
| 8/8/94 | | | | | | | <0.01 | <0.02 | 0.6 |
| 6/2/94 | | | | <0.01 | <0.04 NQ | 0.6 | | | |
| 3/7/94 | <0.01 | <0.02 | 0.6 | | | | | | |
| 11/15/93 | | | | <0.01 | <0.02 | | | | |
| 10/27/93 | | | | | | <0.5 NQ | | | |
| 9/16/93 | | | | | | 0.5 | | | |
| 6/24/93 | | | | <0.01 | <0.02 | | | | |
| 5/25/93 | | | | | | 0.6 | | | |
| 1/13/93 | | | | | | 0.6 | | | |
| 10/20/92 | | | 0.7 | | | | | | |
| 8/6/92 | | | 1.0 | | | | | | |
| 5/11/92 | | | | | | 1.0 | | | |
| 3/27/92 | | | 1.1 | | | | | | |
| 12/13/91 | | | | <0.02 | <0.02 | | | | |
| 8/26/91 | <0.02 | <0.04 NQ | | | | | | | |
| 6/13/91 | | | | <0.02 | <0.02 | | | | |
| 10/11/90 | | | | <0.02 | <0.04 NQ | 1.2 | | | |
| 8/6/90 | | | | | | | <0.02 | <0.04 NQ | <1.0 NQ |
| 7/17/90 | | | | | | <1.0 NQ | | | |
| 4/12/90 | <0.02 | <0.05 NQ | <1.0 NQ | | | | | | |
| 2/16/90 | <0.02 | <0.02 | <1.0 NQ | | | | | | |
| 2/27/89 | | | 1.3 | | | 1.1 | | | |

EDB, DBCP AND TCP DATA SUMMARY FOR KUNIA I AND II WELLS, HONOULIULI I AND II WELLS AND HAWAII COUNTRY CLUB WELL

| HONOULIULI I WELLS<br>EDB, DBCP AND TCP DATA SINCE 1990 | | | | | | |
|---|---|---|---|---|---|---|
| Date | Pump 1 | | | Pump 2 | | |
| | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) |
| 9/17/92 | | | <0.2 | | | <0.2 |
| 2/19/91 | <0.02 | <0.02 | <0.3 | | | |
| 2/16/90 | <0.02 | <0.02 | <0.3 | | | |

**Note:**
**The Honouliuli I Wells have been out of service since 11/9/92 due to high chloride levels.**

| HONOULIULI II WELLS<br>ALL EXISTING EDB, DBCP AND TCP DATA | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Pump 1 | | | Pump 2 | | | Pump 3 | | | Pump 4 | | |
| | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) |
| 10/97 | <0.01 | <0.01 | <0.1 | | | | <0.01 | <0.01 | <0.1 | <0.01 | <0.01 | <0.1 |
| 4/97 | <0.01 | <0.01 | <0.1 | | | | <0.01 | <0.01 | <0.1 | <0.01 | <0.01 | <0.1 |
| 12/3/96 | | | | | | | | | <0.2 | | | |
| 3/3/94 | | | | | | <0.2 | | | <0.2 | | | <0.2 |
| 11/4/93 | | | | <0.01 | <0.02 | | <0.01 | <0.02 | | | | |
| 9/2/93 | | | <0.2 | | | <0.2 | | | | | | |
| 8/25/93 | <0.01 | <0.02 | | | | | <0.01 | <0.02 | | | | |
| 6/15/93 | | | | | | | <0.01 | <0.02 | | | | |
| 6/9/93 | <0.01 | <0.02 | | <0.01 | <0.02 | | | | | | | |
| 5/18/93 | | | <0.2 | | | <0.2 | | | | | | |
| 2/3/93 | | | | | | | <0.02 | <0.02 | | | | |
| 2/2/93 | <0.02 | <0.02 | | | | | | | | <0.02 | <0.02 | |
| 1/22/93 | | | | | | | | | <0.2 | | | <0.2 |
| 10/22/92 | | | <0.2 | | | | | | | | | |
| 9/17/92 | | | <0.2 | | | | | | <0.2 | | | |
| 10/30/89 | | | | | | | | | | | | <0.3 |

| HAWAII COUNTRY CLUB WELL<br>EDB, DBCP AND TCP LEVELS SINCE 1990 | | | |
|---|---|---|---|
| Date | Pumphead | | |
| | EDB (ug/l) | DBCP (ug/l) | TCP (ug/l) |
| 5/12/98[2] | NP | 0.7 | NP |
| 4/29/98[2] | NP | 0.74 | NP |
| 11/19/97 | <0.04 NQ | 0.06 | <0.5 NQ |
| 7/24/97 | <0.04 NQ | 0.06 | <0.5 NQ |
| 4/23/97 | <0.04 NQ | 0.07 | |
| 3/19/97 | <0.04 NQ | 0.06 | |
| 10/24/96 | | | <0.5 NQ |
| 10/17/96 | <0.04 NQ | <0.02 | |
| 3/9/93 | <0.02 | <0.04 NQ | |
| 4/4/91 | | | <0.3 |
| 7/17/90 | <0.02 | <0.04 NQ | |
| 4/12/90 | <0.02 | <0.02 | <0.3 |

**Note:**
**NQ - Not quantifiable. Compound detected below instrument detection limit.**
**Source - HDOH Safe Drinking Water Branch.**
**[1]TCP was detected in these wells at levels of .7 - .8 µg/L during 1997 (Personal communication, Mr. Chester Lao, BWS).**
**NP - Not Provided.**
**[2]Source is Hawaii Department of Health (1998).**

TABLE 3-4

HONOLULU, HAWAII
NORMALS, MEANS AND EXTREMES

| | (a) | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMPERATURE (Deg. F) | | | | | | | | | | | | | | |
| Normals | | | | | | | | | | | | | | |
| Daily Maximum | | 80.1 | 80.5 | 81.6 | 82.8 | 84.7 | 86.5 | 87.5 | 88.7 | 88.5 | 86.9 | 84.1 | 81.2 | 84.4 |
| Daily Minimum | | 65.6 | 65.4 | 67.2 | 68.7 | 70.3 | 72.2 | 73.5 | 74.2 | 73.5 | 72.3 | 70.3 | 67 | 70 |
| Monthly | | 72.9 | 73 | 74.4 | 75.8 | 77.5 | 79.4 | 80.5 | 81.4 | 81 | 79.6 | 77.2 | 74.1 | 77.2 |
| Extremes | | | | | | | | | | | | | | |
| Record Highest | 26 | 87 | 88 | 88 | 89 | 93 | 92 | 94 | 93 | 95 | 94 | 93 | 89 | 95 |
| Year | | 1987 | 1984 | 1987 | 1990 | 1988 | 1995 | 1995 | 1995 | 1994 | 1984 | 1986 | 1995 | Sep-94 |
| Record Lowest | 26 | 53 | 53 | 55 | 57 | 60 | 65 | 66 | 67 | 66 | 61 | 57 | 54 | 53 |
| Year | | 1972 | 1983 | 1976 | 1985 | 1989 | 1982 | 1990 | 1984 | 1985 | 1993 | 1990 | 1962 | Feb-83 |
| NORMAL DEGREE DAYS | | | | | | | | | | | | | | |
| Heating (base 65 Deg. F) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cooling (base 65 Deg. F) | | 245 | 224 | 291 | 324 | 388 | 432 | 481 | 508 | 480 | 453 | 366 | 282 | 4474 |
| % OF POSSIBLE SUNSHI | 43 | 65 | 67 | 71 | 70 | 71 | 73 | 76 | 77 | 77 | 70 | 63 | 62 | 70 |
| MEAN SKY COVER(tenths) | | | | | | | | | | | | | | |
| Sunrise - Sunset | 49 | 5.4 | 5.5 | 5.8 | 6.1 | 5.9 | 5.5 | 5.3 | 5.2 | 5.2 | 5.6 | 5.7 | 5.5 | 5.6 |
| MEAN NUMBER OF DAYS: | | | | | | | | | | | | | | |
| Sunrise to Sunset | | | | | | | | | | | | | | |
| Clear | 46 | 9.5 | 8.1 | 7.5 | 5.7 | 6.6 | 6.4 | 7.5 | 8.1 | 8.1 | 7.5 | 7.2 | 8.2 | 90.4 |
| Partly Cloudy | 46 | 13 | 12.3 | 13.9 | 14.5 | 15.4 | 17.3 | 18.2 | 17 | 16.1 | 15.1 | 13.7 | 13.8 | 180.2 |
| Cloudy | 46 | 8.5 | 7.8 | 9.4 | 9.8 | 9 | 6.3 | 5.3 | 5.9 | 5.9 | 8.4 | 9.1 | 9 | 94.6 |
| Precipitation | | | | | | | | | | | | | | |
| .01 inches or more | 46 | 9.4 | 9.2 | 8.8 | 8.9 | 7.2 | 5.7 | 7.3 | 6.2 | 7 | 8.7 | 9 | 10.2 | 97.6 |
| Snow, Ice Pellets, Hail | | | | | | | | | | | | | | |
| 1.0 inches or more | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thunderstorms | 46 | 0.7 | 1.1 | 0.8 | 0.5 | 0.3 | 0.1 | 0.2 | 0.1 | 0.5 | 0.8 | 0.9 | 0.7 | 6.6 |
| Heavy Fog Visibility | | | | | | | | | | | | | | |
| 1/4 mile or less | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Temperature Deg. F | | | | | | | | | | | | | | |
| Maximum | | | | | | | | | | | | | | |
| 90 Deg. F and above | 26 | 0 | 0 | 0 | 0 | 0.3 | 1.8 | 6 | 11.8 | 11.4 | 4.8 | 0.5 | 0 | 36.7 |
| 32 Deg. F and below | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Minimum | | | | | | | | | | | | | | |
| 32 Deg. F and below | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 Deg. F and below | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AV. STATION PRES. (mb) | 23 | 1015.1 | 1015.5 | 1017.3 | 1017.1 | 1016.9 | 1016.7 | 1016 | 1015.4 | 1014.5 | 1014.7 | 1015 | 1015.4 | 1015.8 |

TABLE 3-4

HONOLULU, HAWAII
NORMALS, MEANS AND EXTREMES

| | (a) | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RELATIVE HUMIDITY (%) | | | | | | | | | | | | | | |
| Hour 04 | 26 | 81 | 79 | 77 | 75 | 75 | 74 | 73 | 74 | 75 | 76 | 78 | 80 | 76 |
| Hour 10 (Local Time) | 26 | 81 | 79 | 73 | 70 | 67 | 66 | 67 | 68 | 69 | 70 | 75 | 79 | 72 |
| Hour 16 | 26 | 61 | 59 | 57 | 55 | 53 | 52 | 51 | 52 | 52 | 55 | 58 | 60 | 55 |
| Hour 22 | 26 | 73 | 72 | 71 | 70 | 69 | 68 | 68 | 69 | 69 | 70 | 72 | 73 | 70 |
| PRECIPITATION (in.) | | | | | | | | | | | | | | |
| Water Equivalent | | | | | | | | | | | | | | |
| Normal | | 3.55 | 2.21 | 2.2 | 1.54 | 1.13 | 0.5 | 0.59 | 0.44 | 0.78 | 2.28 | 3 | 3.8 | 22.02 |
| Maximum Monthly | 49 | 14.74 | 13.8 | 20.79 | 8.92 | 7.23 | 2.46 | 2.33 | 3.08 | 2.74 | 11.15 | 14.72 | 17.29 | 20.79 |
| Year | | 1949 | 1955 | 1951 | 1963 | 1965 | 1971 | 1989 | 1959 | 1947 | 1978 | 1965 | 1987 | Mar-51 |
| Minimum Monthly | 49 | 0.18 | 0.06 | 0.01 | 0.01 | 0.05 | T | 0.03 | T | 0.05 | 0.11 | 0.03 | 0.06 | T |
| Year | | 1986 | 1983 | 1957 | 1960 | 1949 | 1959 | 1950 | 1974 | 1977 | 1957 | 1962 | 1976 | Aug-74 |
| Maximum in 24 hrs | 46 | 6.72 | 6.88 | 17.07 | 4.21 | 3.44 | 2.28 | 2.2 | 2.35 | 1.4 | 7.57 | 9.15 | 8.25 | 17.07 |
| Year | | 1963 | 1955 | 1958 | 1972 | 1965 | 1967 | 1989 | 1959 | 1963 | 1978 | 1954 | 1987 | Mar-58 |
| Snow, Ice Pellets, Hail | | | | | | | | | | | | | | |
| Maximum Monthly | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Year | | | | | | | | | | | | | | |
| Maximum in 24 hrs | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Year | | | | | | | | | | | | | | |
| WIND | | | | | | | | | | | | | | |
| Mean Speed (mph) | 46 | 9.5 | 10.1 | 11.3 | 11.8 | 11.8 | 12.6 | 13.1 | 12.9 | 11.2 | 10.5 | 10.7 | 10.4 | 11.3 |
| Prevailing Direction | | | | | | | | | | | | | | |
| through 1964 | | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE | ENE |
| Fastest Mile | | | | | | | | | | | | | | |
| Direction | 15 | 7 | 0 | 0 | 6 | 13 | 5 | 7 | 4 | 13 | 7 | 20 | 6 | 20 |
| Speed(mph) | | 32 | 35 | 30 | 31 | 30 | 26 | 28 | 28 | 38 | 25 | 46 | 33 | 46 |
| Year | | 1982 | 1990 | 1990 | 1980 | 1985 | 1981 | 1980 | 1982 | 1992 | 1981 | 1982 | 1993 | Nov-82 |
| Peak Gust | | | | | | | | | | | | | | |
| Direction | 12 | NE | NE | NE | E | E | E | NE | E | SE | NE | NE | NE | NE |
| Speed(mph) | 12 | 41 | 46 | 51 | 41 | 39 | 35 | 40 | 36 | 49 | 35 | 40 | 46 | 51 |
| Date | | 1987 | 1990 | 1994 | 1995 | 1985 | 1995 | 1984 | 1994 | 1992 | 1994 | 1986 | 1993 | Mar-94 |

(a) - Length of Record in years, although individual months may be missing.
0.* or * - The value is between 0.0 and 0.05.
Normals - Based on the 1961 - 1990 record period.
Extremes - Dates are the most recent occurrence.
Wind Dir.- Numerals show tens of degrees clockwise from true north. "00" indicates calm.
Resultant Directions are given to whole degrees.

Source: Western Region Climate Center (1998).



Golder Associates

# KUNIA VILLAGE AREA RAINFALL DATA

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 1.00 | 0.68 | 3.44 | 3.43 | 6.90 | 3.80 | 0.20 | 0.53 | 0.61 | 0.64 | 0.52 | 4.09 | 25.84 |
| 1978 | 1.55 | 0.20 | 3.70 | 4.32 | 4.29 | 2.82 | 0.44 | 1.90 | 0.60 | 7.67 | 5.57 | 2.98 | 36.04 |
| 1979 | 4.79 | 18.48 | 0.81 | 1.02 | 1.14 | 1.18 | 0.37 | 2.00 | 1.33 | 0.94 | 2.97 | 3.28 | 38.31 |
| 1980 | 15.88 | 3.74 | 5.67 | 2.26 | 0.87 | 4.23 | 0.86 | 0.50 | 1.55 | 2.28 | 1.11 | 5.82 | 44.77 |
| 1981 | 1.67 | 3.71 | 1.37 | 1.03 | 2.91 | 0.95 | 1.06 | 1.54 | 0.74 | 2.26 | 3.71 | 7.32 | 28.27 |
| 1982 | 19.55 | 5.04 | 6.26 | 5.9 | 1.43 | 3.00 | 0.91 | 3.39 | 1.71 | 10.26 | 5.68 | 5.21 | 68.34 |
| 1983 | 1.02 | 0.29 | 1.08 | 1.68 | 0.67 | 1.47 | 1.55 | 1.45 | 2.39 | 0.98 | 0.37 | 1.59 | 14.54 |
| 1984 | 1.22 | 2.51 | 3.45 | 3.96 | 0.47 | 0.15 | 1.44 | 0.16 | 0.25 | 0.99 | 3.01 | 8.21 | 25.82 |
| 1985 | 4.49 | 5.93 | 2.07 | 1.04 | 0.52 | 0.88 | 0.63 | 0.75 | 5.03 | 9.88 | 4.43 | 2.09 | 37.74 |
| 1986 | 1.51 | 3.62 | 1.18 | 1.93 | 1.53 | 1.04 | 2.41 | 0.79 | 4.21 | 1.77 | 4.00 | 1.80 | 25.79 |
| 1987 | 0.88 | 2.02 | 1.31 | 2.62 | 1.15 | 2.16 | 0.97 | 0.70 | 3.17 | 0.80 | 3.06 | 17.04 | 35.88 |
| 1988 | 3.36 | 0.74 | 1.94 | 1.93 | 1.53 | 0.11 | 0.90 | 1.37 | 2.69 | 2.27 | 4.69 | 10.10 | 31.63 |
| 1989 | 5.29 | 10.16 | 5.07 | 3.13 | 0.50 | 1.06 | 2.72 | 0.85 | 0.92 | 13.34 | 1.85 | 2.72 | 47.61 |
| 1990 | 8.08 | 4.63 | 7.91 | 0.75 | 1.18 | 0.43 | 1.81 | 0.07 | 2.15 | 3.46 | 7.03 | 7.60 | 45.10 |
| 1991 | 2.94 | 2.36 | 13.35 | 2.56 | 1.02 | 1.94 | 0.87 | 2.05 | 2.18 | 11.09 | 0.59 | 3.40 | 44.35 |
| 1992 | 1.62 | 4.83 | 1.50 | 0.34 | 1.94 | 1.06 | 1.54 | 1.17 | 3.26 | 2.94 | 4.01 | 11.33 | 35.54 |
| 1993 | 2.94 | 1.89 | 0.25 | 1.08 | 1.24 | 0.75 | 3.86 | 1.80 | 1.86 | 4.65 | 1.57 | 1.98 | 23.87 |
| 1994 | 2.10 | 7.96 | 7.11 | 1.39 | 1.23 | 1.80 | 1.00 | 0.59 | 2.25 | 8.07 | 0.48 | 2.21 | 36.19 |
| 1995 | 1.63 | 3.21 | 2.43 | 1.46 | 0.48 | 0.69 | 0.89 | 1.17 | 0.40 | 1.62 | 2.23 | 1.41 | 17.62 |
| 1996 | 8.05 | 2.30 | 6.79 | 1.23 | 0.56 | 4.98 | 2.03 | 2.62 | 3.78 | 0.71 | 26.99 | 5.64 | 65.68 |
| 1997 | 13.12 | 1.68 | 7.48 | 2.22 | 3.46 | 1.09 | 2.15 | 1.00 | 1.42 | 2.20 | 1.65 | 1.63 | 39.10 |
| 1998 | 1.58 | 0.96 | | | | | | | | | | | 2.54 |
| Average | 4.74 | 3.95 | 4.01 | 2.16 | 1.67 | 1.69 | 1.36 | 1.26 | 2.02 | 4.23 | 4.07 | 5.12 | 36.57 |

Data for the Kunia Well Site.
Source - DMFP (1998e)

WELL CONSTRUCTION SUMMARY OF SELECTED AREA WELLS

| Well No. | WELL NAME | YEAR DRILLED | DRILLER | LATITUDE | LONGITUDE | OWNER/USER | OLD NUMBER | CASING DIA, in | GROUND ELEV., ft msl | WELL DEPTH, ft | SOLID CASE | PERF CASE | USE | INIT HEAD, ft msl | TEST GPM | TEST DDOWN | GEOLOGY | SPEC CAPAC | AQUIFER | LATEST HEAD, ft msl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2004-04 | MAKAKILO | 1981 | ROSCOE MOSS | 212043 | 1580446 | HONOLULU BWS | | 14 | 141 | 268 | 188 | | MUN | 14.90 | 1118 | 0.8 | | 1398 | 30204 | |
| 2103-03 | BARBERS PT SHAFT | 1943 | | 212131 | 1580355 | U S NAVY | SH14- | 72 | 200 | 204 | | | DOM | 14.10 | | | TWDC | | 30204 | 16.70 |
| 2201-10 | WAIPAHU | 1949 | MULLIN | 212250 | 1580158 | HONOLULU BWS | T41- | 12 | 84 | 113 | 92 | | OBS | 20.30 | | | TKB | | 30203 | 18.40 |
| 2302-01 | KUNIA I P1 | 1957 | SAMSON-SMOCK | 212318 | 1580208 | HONOLULU BWS | 256-2A | 16 | 201 | 350 | 221 | | MUN | 20.80 | 1130 | 3.6 | TKB | 314 | 30203 | 23.80 |
| 2302-02 | KUNIA I P2 | 1957 | SAMSON-SMOCK | 212318 | 1580208 | HONOLULU BWS | 256-2B | 16 | 201 | 338 | 221 | | MUN | 20.90 | 1125 | 0.6 | TKB | 1406 | 30203 | 22.30 |
| 2302-03 | KUNIA I P3 | 1972 | WAT RES INTL | 212316 | 1580205 | HONOLULU BWS | | 16 | 206 | 427 | 246 | | MUN | | 1936 | 4.2 | | 465 | 30203 | |
| 2302-04 | KUNIA I P4 | 1972 | WAT RES INTL | 212316 | 1580205 | HONOLULU BWS | | 16 | 201 | 420 | 241 | | MUN | | 3429 | 26.6 | | 129 | 30203 | |
| 2303-01 | HONOULIULI I #1 | 1986 | ROSCOE MOSS | 212326 | 1580316 | HONOLULU BWS | | 14 | 412 | 625 | 550 | | UNU | 16.00 | 1760 | 2.0 | | 880 | 30204 | |
| 2303-02 | HONOULIULI I #2 | 1987 | ROSCOE MOSS | 212328 | 1580313 | HONOLULU BWS | | 14 | 411 | 610 | 550 | | MUN | 16.00 | 1750 | 2.1 | | 833 | 30204 | 15.92 |
| 2303-03 | HONOULIULI II #1 | 1987 | ROSCOE MOSS | 212339 | 1580344 | HONOLULU BWS | | 14 | 419 | 534 | 450 | | MUN | 17.04 | 1758 | 11.1 | | 158 | 30204 | |
| 2303-04 | HONOULIULI II #2 | 1988 | ROSCOE MOSS | 212342 | 1580344 | HONOLULU BWS | | 14 | 421 | 555 | 455 | | MUN | 12.20 | 1760 | 0.6 | | 2933 | 30204 | |
| 2303-05 | HONOULIULI II #3 | 1989 | ROSCOE MOSS | 212347 | 1580343 | HONOLULU BWS | | 14 | 432 | 545 | 465 | | MUN | 16.00 | 1750 | 1.0 | | 1750 | 30204 | |
| 2303-06 | HONOULIULI II #4 | 1989 | ROSCOE MOSS | 212347 | 1580346 | HONOLULU BWS | | 14 | 432 | 535 | 455 | | MUN | 17.40 | 1760 | 0.9 | | 1956 | 30204 | |
| 2303-07 | HONOULIULI MON | 1992 | ROSCOE MOSS | 212313 | 1580324 | EWA WTR DEV | | 4 | 299 | 1055 | | | OBS | | | | | | 30204 | |
| 2307-01[b] | NANAKULI | 1940 | HEIZER | 212349 | 1580724 | HONOLULU BWS | T15- | 1 | 479 | 489 | 469 | 489 | OBS | 2.70 | | | TWDC | | 30301 | 2.40 |
| 2402-01 | KUNIA II P1 | 1969 | ROSCOE MOSS | 212410 | 1580231 | HONOLULU BWS | 256-4A | 16 | 430 | 575 | 460 | | MUN | 20.60 | 2069 | 1.4 | TKB | 1478 | 30203 | |
| 2402-02 | KUNIA II P2 | 1969 | LAYNE INT | 212408 | 1580230 | HONOLULU BWS | 256-4B | 16 | 430 | 575 | 465 | | MUN | 24.60 | 2143 | 13.2 | TKB | 162 | 30203 | |
| 2402-03 | KUNIA II P3 | 1990 | ROSCOE MOSS | 212409 | 1580227 | HONOLULU BWS | | 16 | 417 | 610 | 460 | | UNU | 17.00 | 1760 | | | | 30203 | |
| 2407-01 | NANAKULI | 1940 | HEIZER | 212402 | 1580718 | C&C HONOLULU | T13- | 2 | 625 | 203 | | | | | | | TKB | | 30301 | |
| 2407-02 | NANAKULI | 1940 | HEIZER | 212402 | 1580718 | C&C HONOLULU | T14- | 2 | 625 | 178 | | | | | | | TKB | | 30301 | |
| 2603-01 | WAIKELE | 1981 | PACIFIC DRLG | 212618 | 1580338 | HAW CNTRY CLUB | | 12 | 745 | 991 | 726 | 777 | IRR | 23.63 | 300 | 80.0 | TKB | 4 | 30203[a] | |
| 2703-01 | KUNIA CAMP #1 | 1946 | CAMAY | 212741 | 1580342 | DEL MONTE | | 12 | 847 | 976 | 626 | 976 | IRR | 24.91 | 300 | 2.4 | TKB | 125 | 30203[a] | 25.16 |
| 2702-01 | WAIKAKALAUA MW-6 | 1988 | PR DRILLING | 212726 | 1580215 | U S AIR FORCE | | 4 | 688 | 155 | 140 | 155 | OBS | | | | | | 30203 | |
| 2702-02 | WAIKAKALAUA MW-7 | 1988 | PR DRILLING | 212731 | 1580211 | U S AIR FORCE | | 4 | 694 | 155 | 140 | 155 | OBS | | | | | | 30203 | |
| 2702-03 | | | | | | U S AIR FORCE | | 4 | 672 | 670 | 642 | 662 | OBS | | | | | | | |
| 2702-04 | | | | | | U S AIR FORCE | | 4 | 718 | 730 | 696 | 716 | OBS | | | | | | | |
| 2702-05 | | | | | | U S AIR FORCE | | 4 | 710 | 730 | 686 | 707 | OBS | | | | | | | |
| | MW006 | 1997 | | | | U S AIR FORCE | | 4 | | 701 | 677 | 697 | OBS | | | | | | | |
| | RW001 | 1997 | | | | U S AIR FORCE | | 4 | | 700 | 663 | 683 | OBS | | | | | | | |
| 2803-01 | KUNIA | 1957 | SAMSON-SMOCK | 212632 | 1580327 | U S NAVY | T59- | 1 | 866 | 1020 | 1020 | | | 192.20 | | | | | 30501 | |
| 2803-02 | KUNIA BATTERY | 1958 | PACIFIC DRLG | 212630 | 1580328 | U S NAVY | 330-7A | 16 | 860 | 1020 | 892 | | | 191.80 | 17 | 15.0 | | 1 | 30501 | |
| 2803-03 | KUNIA BATTERY | 1958 | PACIFIC DRLG | 212633 | 1580327 | U S NAVY | 330-7B | 16 | 863 | 1020 | 897 | | UNU | 203.60 | | | | | 30501 | |
| 2803-04 | KUNIA | 1959 | PACIFIC DRLG | 212645 | 1580320 | U S NAVY | T73- | | 757 | 757 | | | | 273.00 | | | | | 30501 | |
| 2803-05 | DEL MONTE PUMP 3 | 1959 | PACIFIC DRLG | 212638 | 1580327 | DEL MONTE CORP | | 16 | 857 | 1020 | 661 | 867 | DOM | 277.40 | 1300 | 9.4 | | 138 | 30501 | |
| 2803-06 | KUNIA BATTERY | 1959 | PACIFIC DRLG | 212644 | 1580321 | U S NAVY | 330-7D | 16 | 757 | 646 | 604 | | UNU | 276.80 | 2500 | 3.1 | | 806 | 30501 | |
| 2803-07 | DEL MONTE PUMP 4 | 1979 | WAT RES INTL | 212630 | 1580326 | DEL MONTE CORP | | 16 | 872 | 990 | 830 | | IRR | 201.00 | 2300 | 29.9 | | 77 | 30501 | |

30204 - Ewa system of the Pearl Harbor Aquifer (Waianae Volcanic Series)
30203 - Waipahu system of the Pearl Harbor Aquifer (Koolau Volcanic Series)
30301- Nanakuli system of the Waianae Aquifer (Waianae Volcanic Series)
30501 - Wahiawa system of the Central Aquifer (Schofield High-Level Body)

Mun - Municpal Water Supply Well
OBS - Observation Well
DOM - Domestic Water Supply Well
IRR - Irrigation Water Supply Well
UNU - Unused

[a] - Miyamoto et al. (1986) and Oki (1998) indicate these wells as being installed in the Waianae section of the Pearl Harbor Basal Aquifer.
[b] - Filled May 1969.

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TABLE 3-7

WATER LEVEL MEASUREMENTS IN PIEZOMETERS

| Piezometer | Water level ft below top of 1" PVC (4/21/97) | Water level ft below top of 1" PVC (6/5/97) | Water Level ft below top of 1" PVC (9/3/97) | Water Level ft below top of 1" PVC (10/25/97) | Elevation of top of 1-inch 1" PVC feet AMSL | Water Level Elevation feet AMSL (4/21/97) | Water Level Elevation feet AMSL (6/5/97) | Water Level Elevation feet AMSL (9/3/97) | Water Level Elevation feet AMSL (10/25/97) |
|---|---|---|---|---|---|---|---|---|---|
| P-1 | 27.76 | 29.13 | 32.99 | na | 851.33 | 823.57 | 822.20 | 818.34 | na |
| P-2 | 21.94 | 23.43 | 27.04 | 28.62 | 847.17 | 825.23 | 823.74 | 820.13 | 818.55 |
| P-3 | 25.67 | 26.82 | 29.91 | 31.40 | 847.66 | 821.99 | 820.84 | 817.75 | 816.26 |
| P-4 | 31.29 | 32.45 | 35.41 | 36.94 | 848.80 | 817.51 | 816.35 | 813.39 | 811.86 |
| P-5 | 14.22 | 16.71 | 23.87 | 25.25 | 831.61 | 817.39 | 814.90 | 807.74 | 806.36 |
| P-6 | 6.7 | 8.08 | 15.15 | 16.52 | 822.72 | 816.02 | 814.64 | 807.57 | 806.20 |
| P-7 | 15.94 | 18.08 | na | na | 822.32 | 806.38 | 804.24 | na | na |
| P-8 | 23.6 | 28.43 | 40.98 | 42.21 | 821.62 | 798.02 | 793.19 | 780.64 | 779.41 |

na - Not Applicable. Well Dry.

TABLE 3-8

WATER LEVEL MEASUREMENTS IN MONITORING WELLS

| Monitoring Well | Elevation of Top of PVC, ft AMSL | 6/5/97 | | 8/18/97 | | 9/3/1997[a] | | 10/25/97 | | 1/12/1998[b] | | 5/12/1998[c] | | 7/27/1998[d] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL | Depth, ft bgs | Elevation, ft AMSL |
| MW-1 | 846.45 | 48.19 | 798.26 | 49.77 | 796.68 | 50.16 | 796.29 | 51.08 | 795.37 | 53.2 | 793.25 | 56.5 | 789.95 | 58.8 | 787.65 |
| MW-2 | 823.02 | 72.27 | 750.75 | 73.59 | 749.43 | 73.89 | 749.13 | 74.21 | 748.81 | 75.3 | 747.72 | 77.5 | 745.52 | 78.3 | 744.72 |
| MW-3 | 821.74 | 52.61 | 769.13 | 52.43 | 769.31 | 52.9 | 768.84 | 54.92 | 766.82 | 58.9 | 762.84 | 61 | 760.74 | 64.65 | 757.09 |
| MW-3s | 821.32 | | | | | 22.05 | 799.27 | 27.38 | 793.94 | 30.6 | 790.72 | 37.4 | 783.92 | 43 | 778.32 |
| MW-5 | 819.14 | | | | | 51.62 | 767.52 | 54.3 | 764.84 | 61.2 | 757.94 | 59.6 | 759.54 | 61.9 | 757.24 |
| MW-6 | 817.1 | | | | | | | 58.04 | 759.06 | 61.6 | 755.5 | 73.3 | 743.8 | 75.3 | 741.8 |

[a] Over the period 9/3/97 to 9/6/97
[b] Over the period 1/12/98 to 1/13/98
[c] Over the period 5/12/98 to 5/13/98
[d] Over the period 7/27/98 to 7/28/98

bgs - below ground surface
AMSL - above mean sea level

TABLE 3-9

SUMMARY OF PERCHED AQUIFER HYDRAULIC CONDUCTIVITY MEASUREMENTS

| Well | Test Type | Sample/Sample Pack Interval, ft bgs | Sample ID | Sample Description | K, cm/s | |
|---|---|---|---|---|---|---|
| MW-1 | Lab | 70-72 | DM00306 | silty clay (CL) - saprolite | 3.10E-07 | |
| MW-2 | Lab | 33-35 | DM00314 | silty clay (CL) - saprolite | 1.80E-06 | |
| MW-2 | Lab | 50-52 | DM00316 | silty clay (CL) - saprolite | 1.40E-05 | |
| MW-2 | Lab | 68-69 | DM00319 | silty clay (CL) - saprolite | 7.30E-06 | |
| MW-3 | Lab | 35-37 | DM00329 | Clay (CH) - saprolite | 5.50E-07 | |
| MW-3 | Lab | 48-49 | DM00331 | silty clay (CL) - saprolite | 9.20E-06 | |
| MW-3 | Lab | 55-57 | DM00333 | silty clay (CL) - saprolite | 1.30E-05 | |
| MW-1 | Slug | 79-92.2 | NA | Saprolite | Injection | 9.19E-06 |
| | | | | | withdrawal | 6.03E-06 |
| MW-2 | Slug | 66-79 | NA | Saprolite | Injection | 5.17E-05 |
| | | | | | withdrawal | 7.63E-05 |
| MW-3S | Slug | 27-40.4 | NA | Saprolite | Injection | 3.24E-06 |
| | | | | | withdrawal | 8.60E-06 |
| MW-3 | Slug | 59-74 | NA | Saprolite | Injection | 1.02E-05 |
| | | | | | withdrawal | 6.37E-06 |
| MW-5 | Slug | 57-70 | NA | Saprolite | Injection | 8.56E-05 |
| | | | | | withdrawal | 2.11E-04 |
| MW-6 | Slug | 50-78 | NA | Saprolite | Injection | 2.52E-05 |
| | | | | | withdrawal | - |
| P-3 | Slug | 21-45 | NA | Saprolite | Injection | 3.67E-05 |
| | | | | | withdrawal | - |
| P-4 | Slug | 22-45 | NA | Saprolite | Injection | 4.68E-06 |
| | | | | | withdrawal | - |
| P-6 | Slug | 8-31 | NA | Saprolite | Injection | 5.17E-05 |
| | | | | | withdrawal | - |

SUMMARY OF PERCHED AQUIFER PHYSICAL TESTING

| Well | Sample ID | Depth, ft bgs | Wet Density, pcf | Dry Density, pcf | Specific Gravity | Porosity | % Passing | | Sample Description | % Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | #4 | #200 (% fines) | | |
| MW-1 | DM00295 | 1-3 | 103.2 | 77.8 | 2.93 | 0.57 | 100 | 75.9 | CH | |
| MW-1 | DM00296 | 3-5 | 110.2 | 82.5 | 2.98 | 0.56 | 98.7 | 80.6 | CH | |
| MW-1 | DM00297 | 9-11 | 98.6 | 66.7 | 2.9 | 0.63 | 100 | 87 | CL | |
| MW-1 | DM00299 | 27-29 | 105.8 | 68.6 | 2.9 | 0.62 | 100 | 83 | CL | |
| MW-1 | DM00300 | 35-37 | 102 | 63.5 | 2.93 | 0.65 | 100 | 92 | CH | |
| MW-1 | DM00306 | 70-72 | | | | | | | CL | 0.039 |
| MW-2 | DM00309 | 2-4 | 116.6 | 85.7 | 2.9 | 0.53 | 100 | 94.7 | CH | |
| MW-2 | DM00310 | 4-6 | 118.7 | 86.8 | 2.99 | 0.53 | 100 | 94 | CH | |
| MW-2 | DM00311 | 9-11 | 104.4 | 70.9 | 2.8 | 0.59 | 100 | 88.8 | CH | |
| MW-2 | DM00313 | 25-26 | 110.3 | 74.1 | 2.84 | 0.58 | 100 | 90.5 | CL | |
| MW-2 | DM00314 | 33-35 | 112 | 74.3 | 2.83 | 0.58 | 100 | 61.5 | CL | 0.039 |
| MW-2 | DM00316 | 50-52 | | | | | | | CL | 0.098 |
| MW-2 | DM00319 | 68-69 | | | | | | | CL | 0.079 |
| MW-3 | DM00321 | 2-4 | 108.9 | 80.6 | 2.88 | 0.55 | 95.8 | 80.7 | CH | |
| MW-3 | DM00322 | 4-6 | 103.3 | 71.3 | 2.86 | 0.6 | 99.3 | 89.5 | CL | |
| MW-3 | DM00323 | 9-11 | 97.7 | 72 | 2.89 | 0.6 | 96.5 | 89.7 | CH | |
| MW-3 | DM00326 | 24-26 | 104.1 | 65.8 | 2.87 | 0.63 | 100 | 95.4 | CH | |
| MW-3 | DM00329 | 35-37 | 104.8 | 65 | 2.85 | 0.63 | 100 | 94 | CH | 0.098 |
| MW-3 | DM00331 | 48-49 | | | | | | | CL | 0.078 |
| MW-3 | DM00333 | 55-57 | | | | | | | CL | < 0.01 |

SUMMARY OF BASAL WELL WATER NOTES WHILE DRILLING

| Date | Time | Water Level [ft BGS] | Duration Borehole Idle Prior to the Measurement [hours] | Borehole Depth At Time of Measurement [ft BGS] | Cased Part of Borehole [ft BGS] | Drilling Fluid | Comments |
|---|---|---|---|---|---|---|---|
| 9/12/97 | 8:30 | 37.2 | 17.5 | 160 | 0 - 10.2 | foam | Electric Tape |
| 9/15/97 | 7:30 | 36.8 | 15 | 202.8 | 0 - 10.2 | foam | Electrc Tape |
| 9/16/97 | 6:15 | 38.3 | 12 | 202.8 | 0 - 10.2 | foam | Electric Tape |
| 9/16/97 | 8:30 | 38.3 | 0.5 | 202.8 | 0 - 10.2 | foam | Electic Tape |
| 9/19/97 | 7:30 | Dry | 13 | 247 | 0 - 202.8 | foam | Electric Tape |
| 9/20/97 | 8:00 | Dry | 14 | 305 | 0 - 202.8 | foam | Electic Tape |
| 9/22/97 | 8:00 | Dry | 40 | 341 | 0-202.8 | foam | Electric Tape |
| 9/23/97 | 8:00 | Dry | 16 | 354 | 0-202.8 | foam | Based on Return Fluid |
| 9/25/97 | 8:00 | Dry | 8 | 447 | 0-202.8 | foam | Based on Return Fluid |
| 9/26/97 | 8:00 | Dry | 11 | 512 | 0-202.8 | foam | Based on Return Fluid |
| 9/27/86 | 8:00 | Dry | 12 | 565 | 0-202.8 | foam | Based on Return Fluid |
| 9/28/97 | 8:00 | Dry | 12 | 600 | 0-202.8 | foam | Based on Return Fluid/ E.T. |
| 9/29/97 | 8:00 | Dry | 12 | 646 | 0-202.8 | foam | Based on Return Fluid/ E.T. |
| 9/29/97 | 16:00 | 826.8 | Driller noted some water while drilling 658 to 705 ftBGS based on moisture content of foam | | | | |
| 10/3/97 | 8:00 | 826.53 | 12 | 850 | 0-202.8 | foam | Electric Tape |
| 10/5/97 | 9:00 | 826.8 | 12 | 943 | 0-202.8 | foam | Electric Tape |
| 10/7/97 | 8:00 | 826.5 | 12 | 993.5 | 0-202.8 | foam | Electric Tape |

TABLE 3-12

WATER LEVEL MEASUREMENTS IN BASAL WELLS

| Well | Date | Measuring Point (MP) | MP Elevation, ft AMSL | Depth to Water, ft | Elevation, ft AMSL | Instrument | Person |
|---|---|---|---|---|---|---|---|
| Kunia Well (2703-01) | 3/15/97 | Concrete Pad | 847.25 | 824.3 | 22.95 | GAI Solinst #HD0147 | R. Long (GAI) |
| | 9/9/97 | Concrete Pad | 847.25 | 824 | 23.25 | GAI Solinst #HD0147 | J. Wozniewicz (GAI) |
| | 9/10/97 | Concrete Pad | 847.25 | 823.97 | 23.28 | GAI Solinst #HD0147 | J. Wozniewicz (GAI) |
| | 9/12/97 | Concrete Pad | 847.25 | 823.98 | 23.27 | GAI Solinst #HD0147 | J. Wozniewicz (GAI) |
| | 2/11/98 | Top of Drop Pipe | 847.74 | 825.34 | 22.4 | GAI Solinst #HD0147 | C. Oda/J. Mink (DMFP) |
| | 2/18/98 | Top of Drop Pipe | 847.74 | 824.92 | 22.82 | CWRM Tape | J.Mink/C. Oda (DMFP |
| | | | | | | | |
| Basal Monitoring Well (2703-02) | 10/15/97 | Ground Surface | 848.9 | 826 | 22.9 | GAI Solinst #HD0147 | J. Wozniewicz (GAI) |
| | 2/11/98 | Top of Drop Pipe | 852.38 | 829.97 | 22.41 | GAI Solinst #HD0147 | C. Oda (DMFP) |
| | 2/18/98 | Top of Drop Pipe | 852.38 | 829.54 | 22.84 | CWRM Tape | J. Mink/C. Oda (DMFP) |
| | | | | | | | |
| Hawaii Country Club Well (2603-01) | 2/18/98 | Top of Drop Pipe | 745.84 | 723.95 | 21.89 | CWRM Tape | J. Mink/C. Oda (DMFP) |
| | | | | | | | |
| BWS T-41 (2201-10) | 2/10/98 | | | | 19.18 | | C. Lao (BWS) |
| | | | | | | | |
| Honouliuli Monitor Well (2303-07) | 1/18/98 | | | | 15.65 | | T. Nance (Water Res. Engineering) |
| | | | | | | | |

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# GRADIENTS BETWEEN REGIONAL BASAL WELLS

| Well | Head | Kunia Well | | HCC Well | | T-41 | | Honouliuli Monitor Well | |
|---|---|---|---|---|---|---|---|---|---|
| | | dh (ft) | i (ft/mile) | dh (ft) | i (ft/mile) | dh (ft) | i (ft/mile) | dh (ft) | i (ft/mile) |
| Kunia Well | 22.82 | -- | -- | .93 | .59 | 3.64 | .62 | 7.17 | 1.39 |
| HCC Well | 21.89 | -- | -- | -- | -- | 2.71 | .62 | 6.24 | 1.75 |
| T-41 (2201-10) | 19.18 | -- | -- | -- | -- | -- | -- | -- | -- |
| Honouliuli Monitor Well (2303-07) | 15.65 | -- | -- | -- | -- | -- | -- | -- | -- |

**Distance Between Well Pairs**

Kunia Well to HCC Well - 8,350 ft (1.58 mi)
Kunia Well to T-41 - 31,200 ft (5.91 mi)
Kunia Well to Honouliuli Well - 27,200 ft (5.15 mi)
HCC Well to T-41 - 23,000 ft (4.36 mi)
HCC Well to Honouliuli Well - 18,800 ft (3.56 mi)

TABLE 3-14

SUMMARY OF RESULTS FOR ANALYSIS OF PUMPING TEST DATA

| ZONE | PHASE | INNER BOUNDARY | FORMATION | OUTER BOUNDARY | T [m2/s] | K [m/s] | K [ft/day] | S [-] | s | C |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Pumping | WBS & Skin | Homogeneous | Infinite | 3.33E-01 | 7.63E-03 | 2159 | 3.10E-05 | 102 | 2.14E-02 |
| Source | Recovery | WBS & Skin | Homogeneous | Infinite | 3.56E-01 | 8.16E-03 | 2309 | 3.10E-05 | 109 | 4.35E-02 |
| Sensitivity Analyses of Pmping Phase for Source Zone - Lower Limit | | | | | 1.68E-01 | 3.68E-03 | 1041 | 3.10E-05 | | |
| Sensitivity Analyses of Pmping Phase for Source Zone Upper Limit | | | | | 7.40E-01 | 1.70E-02 | 4811 | 3.10E-05 | | |
| | | | | | | | | | | |
| Observation | Pumping | Line Source | Homogeneous | Channel Boundaries | 1.05E+00 | 2.35E-02 | 6651 | 3.16E-05 | N/A | N/A |
| Observation | Recovery | Line Source | Homogeneous | Channel Boundaries | 9.98E-01 | 2.24E-02 | 6339 | 3.16E-05 | N/A | N/A |

Note: Storativity is an assumed parameter in the source zone analysis and matched parameter in the observation zone analysis. The storativity derived in the observation zone analysis is poorly constrained due to poor early time match to the model.

TABLE 4-1

TARGETED COMPOUNDS ANALYZED DURING THE RI
DEL MONTE CORPORATION (OAHU PLANTATION) SUPERFUND SITE

| ANALYTE | Soil Method | Water Method | Quantitation Limit (1) Soil (ug/kg) | Quantitation Limit (1) Water (PPB) (ug/l) | MCLs (2) (ug/l) | Residential Soil (ug/kg) | PRGs (3) Industrial Soil (ug/kg) | Tapwater (ug/l) | Log $K_{ow}$ | $K_H$ (atm*m$^3$ /mol) | Solubility (mg/l) | Vapor Pressure (mm/Hg) | Molecular Weight (g/mol) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemicals of Potential Concern | | | | | | | | | | | | | |
| Ethylene dibromide (EDB) | 8260 | 504.1 | 2.5 | 0.04 | 0.04 | 4.9 | 29.0 | 0.00076 | | 8.80E-04 | 4300 | 11 | 187.9 |
| 1,2-Dibromo-3-chloropropane (DBCP) | 8260 | 504.1 | 2.5 | 0.04 | 0.04 | 320 | 2,100 | 0.048 | | | 1000 | 0.8 | 236.36 |
| cis-1,3-Dichloropropene | 8260 | 8260 | 2.5 | 0.5 | | 81 | 180 | 0.081 | 1.41 | 0.0013 | 1000 | 43 | 110.97 |
| trans-1,3-Dichloropropene | 8260 | 8260 | 2.5 | 0.5 | | 81 | 180 | 0.081 | 1.41 | 0.0013 | 1000 | 34 | 110.97 |
| 1,2-Dichloropropane | 8260 | 8260 | 2.5 | 1 | 5 | 340 | 760 | 0.16 | 2.28 | 0.0023 | 2700 | 42 | 112.99 |
| 1,2,3-Trichloropropane | 8260 | 8260 | 1.5 | 1 | 0.8 | 1.4 | 3.1 | 0.0016 | | | | 2 | 147.44 |
| 1,1,2-Trichloropropane | 8260 | 8260 | 2.5 | 1 | | 15,000 | 51,000 | 30 | | | | | 147.44 |
| Methyl bromide | 8260 | 8260 | 2.5 | 1 | | 550,000 | 1,100,000 | 370 | | | 11700 | | 173.86 |
| Toxaphene (penaphene) | 8080 | 8080 | 150 | 5 | 3 | 400 | 2,700 | 0.061 | 3.3 | 0.063 | 1.75 | 0.2 | 413.82 |
| Lindane (HCH Gamma) | 8080 | 8080 | 2.0 | 0.05 | 0.2 | 420 | 3,200 | 0.052 | 3.7 | 4.80E-07 | 10 | 9.40E-04 | 290.83 |
| Target Compound for Screening | | | | | | | | | | | | | |
| 2,3-Dichloro-1-propene | 8260 | 8260 | 2.5 | 1 | | NA | | | | | 2150 | 53 | 110.97 |
| 3,3-Dichloropropene | 8260 | 8260 | 2.5 | 1 | | NA | | | | | | | 110.97 |
| Trichloronitromethane | 8260 | 8260 | 2.5 | 1 | | NA | | | | | 2000 | 16.9 | 132.35 |
| 1,1-Dichloro-1-nitroethane | 8260 | 8260 | 2.5 | 1 | | NA | | | | | 3.5 | 16 | 143.9 |
| Heptachlor | 8080 | 8080 | 1.7 | 0.05 | 0.4 | 99 | 670 | 0.015 | 5.44 | 0.0023 | 0.18 | 0.0003 | 373.32 |
| Bromacil (Hyvar X) | 632 | 632 | 33 | 1 | | NA | | | | | 815 | 8.00E-04 | 261.11 |
| Diuron (Karmex) | 632 | 632 | 20 | 0.5 | | 110,000 | 2,100,000 | 73 | | | 42 | 3.10E-06 | 233.1 |
| Ametryn (Evik 80W) | 619 | 619 | 33 | 1 | | 490,000 | 9,600,000 | 330 | | | | | 227.35 |
| Fenamiphos (Nemacur 3) | 8141 | 8141 | 33 | 1 | | 14,000 | 270,000 | 9.1 | | | | | |

TABLE 4-1

TARGETED COMPOUNDS ANALYZED DURING THE RI
DEL MONTE CORPORATION (OAHU PLANTATION) SUPERFUND SITE

| ANALYTE | Soil Method | Water Method | Quantitation Limit [1] Soil (ug/kg) | Quantitation Limit [1] Water (PPB) (ug/l) | MCLs [2] (ug/l) | PRGs [3] Residential Soil (ug/kg) | PRGs [3] Industrial Soil (ug/kg) | PRGs [3] Tapwater (ug/l) | Log $K_{ow}$ | $K_H$ (atm*m$^3$ /mol) | Solubility (mg/l) | Vapor Pressure (mm/Hg) | Molecular Weight (g/mol) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| TPH-Diesel | 8015M | 8015M | 10,000 | 500 | | NA | | | | | | | |
| Benzene [4] | 8260 | 8260 | 2.5 | 1 | 5 | 620 | 1,400 | 0.39 | 2.13 | 5.43E-03 | 1780 | 76 | 78.11 |
| Toluene [4] | 8260 | 8260 | 2.5 | 1 | 1,000 | 520,000 | 520,000 | 720 | 2.73 | 6.61E-03 | 515 | 22 | 92.14 |
| Ethylbenzene [4] | 8260 | 8260 | 2.5 | 1 | 700 | 230,000 | 230,000 | 1,300 | 3.15 | 7.90E-03 | 152 | 7 | 106.16 |
| Xylene [4] | 8260 | 8260 | 2.5 | 1 | 10 | 280,000 | 280,000 | 1,400 | 3.16 | | 186.5 | 5.8 | 106.17 |
| | | | | | | | | | | | | | |
| Benzo(a)pyrene | 8310 | 8310 | 1.0 | 0.03 | | 56 | 360 | 0.0092 | | | | | |
| Acenapthene | 8310 | 8310 | 5.0 | 0.14 | | 2,600,000 | 28,000,000 | 370 | | | | | |
| Napthelene | 8310 | 8310 | 5.0 | 0.11 | | 55,000 | 190,000 | 6.2 | | | | | |
| Fluorene | 8310 | 8310 | 1.0 | 0.04 | | 1,800,000 | 22,000,000 | 240 | | | | | |
| Lead, Cadmium | 6010 | 6010 | 1000.0 | 5 | | 400,000 | 1,000,000 | 4 | | | | | |
| Non-Site Target Compounds | | | | | | | | | | | | | |
| Trichloroethylene | 8260 | 8260 | 2.5 | 1 | 5 | 2,700 | 6,100 | 1.6 | 2.53 | 0.0091 | 1100 | 57.8 | 131.39 |
| cis-1,2 Dichloroethylene | 8260 | 8260 | 2.5 | 1 | 70 | 42,000 | 150,000 | 61 | | | 800 | 200 | 96.94 |
| trans-1,2 Dichloroethylene | 8260 | 8260 | 2.5 | 1 | 100 | 62,000 | 210,000 | 120 | 2.09 | 0.384 | 600 | 265 | 96.94 |
| Carbon tetrachloride | 8260 | 8260 | 2.5 | 1 | 5 | 230 | 520 | 0.17 | | 0.0302 | 800 | 90 | 153.82 |

Notes:

(1) Proposed quantitation limits. Limits may change as required.

(2) Maximum Contaminant Levels as of Oct-96. MCLs for EDB, DBCP and 1,2,3-TCP are from Hawaii Administrative Rule Title 11, Chapter 11-20.

(3) EPA Region IX Preliminary Remediation Goals (1998)

(4) BTEX compounds are not specified COPCs and were screened for if TPH-diesel concentrations were equal or greater than 100 mg/kg. However, BTEX was analyzed as part of the EPA Method 8260 analysis so BTEX was screened for in all soils.

(5) PAHs, lead, cadmium, and chromium are not specified COPCs, but were screened for if TPH-diesel concentrations were equal or greater than 100 mg/kg.

Source: ICF (1997)

Golder Associates

TABLE 4-2

COMPOUNDS DETECTED IN VADOSE ZONE SOIL SAMPLES COLLECTED IN THE KUNIA VILLAGE AREA

| | PRGs Soils[a] | Borehole: Depth: Date: | B-1 6 ft. 03/18/97 | B-1 8 ft. 03/18/97 | B-17 4 ft. 03/13/97 | B-17 4 ft. 03/13/97 Dup | B-22[c] 16ft. 08/19/97 | B-23 6ft. 04/08/97 | B-23 6 ft. 04/08/97 Dup | B-24 10ft. 08/19/97 | B-26 4ft. 04/08/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Residential | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| **8260 - VOLATILE ORGANICS** | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 4.9 | UG/KG | 6.8 U | na | 3.3 U | 3.2 U | 3.2 J | 3.3 U | 3.4 U | 3.3 U | 3.3 U |
| 1,2-DICHLOROPROPANE | 340 | UG/KG | 6.8 U | na | 3.3 U | 3.2 U | 3.8 U | 3.3 U | 3.4 U | 3.3 U | 3.3 U |
| ETHYLBENZENE | 230,000 | UG/KG | 29 | na | 3.3 U | 3.2 U | 3.8 U | 3.3 U | 3.4 U | 3.3 U | 3.3 U |
| TOLUENE | 520,000 | UG/KG | 3.1 U | 3.1 U | 3.3 U | 3.3 U | 3.8 U | 3.3 U | 3.4 U | 3.3 U | 3.3 U |
| **8081 - ORGANOCHLORINE PESTICIDES** | | | | | | | | | | | |
| GAMMA-BHC (LINDANE) | 420 | UG/KG | 2.3 U | na | 2.2 U | 2.2 U | na | 1.7 U | 7.1 J | 6.5 | 4.8 |
| HEPTACHLOR | 99 | UG/KG | 2.3 U | na | 2.2 U | 3.2 | na | 1.7 U | 2.4 | 2.3 U | 1.7 U |
| **8015M - FUEL HYDROCARBONS** | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | 5,000[b] | MG/KG | 19000 | 940 | 13 U | 13 U | na | 13 U | 14 U | 16 | 13 U |
| **8310 - POLYAROMATIC HYDROCARBONS** | | | | | | | | | | | |
| ACENAPHTHENE | 18,000[b] | UG/KG | 170 J | 18 UR | na | na | na | na | na | na | na |
| NAPHTHALENE | 41,000[b] | UG/KG | 250 J | 8.5 UR | na | na | na | na | na | na | na |
| FLUORENE | 1,800,000 | UG/KG | 1300 J | 1.3 UR | na | na | na | na | na | na | na |

[a]EPA Region IX Preliminary Remediation Goals (1998)
[b]The values listed for Total Petroleum Hydrocarbons, Acenaphthene and Naphthlene are from the State of Hawaii Department of Health Tier 1 Action Levels (June 1996)
[c]These soil samples were collected in the saturated zone (i.e., below the top of the perched water table)
U - Analyte was not detected above the reported sample quantitation limit
J - The associated value is an estimated quantity
UR - Result is unusable due to not meeting quality control criteria
na - not analyzed
See Appendix A for a summary of all analyses conducted on Kunia Village Area Vadose zone soils
Shading indicates compound was detected in excess of Action Level

TABLE 4-2

COMPOUNDS DETECTED IN VADOSE ZONE SOIL SAMPLES COLLECTED IN THE KUNIA VILLAGE AREA

| | PRGs Soils[a] | Borehole: Depth: Date: | B-27[c] 16ft. 08/19/97 | B-27 16 ft. 08/19/97 Dup | B-28 2ft. 08/19/97 | B-28[c] 26ft. 08/19/97 | B-34 1.5 ft. 08/20/97 | B-34 1.5 ft. 08/20/97 Dup | B-37 1 ft 7/29/98 | B-37 3 ft 7/29/98 | B-38 1 ft 7/29/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Residential | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| **8260 - VOLATILE ORGANICS** | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 4.9 | UG/KG | 3.7 U | 3.5 U | 3 U | 3.7 U | 3.2 U | 3.2 U | 2.5 U | 2.5 U | 0.38 J |
| 1,2-DICHLOROPROPANE | 340 | UG/KG | 3.7 U | 3.5 U | 3.0 U | 30 | 3.2 U | 3.2 U | 2.5 U | 2.5 U | 2.5 U |
| ETHYLBENZENE | 230,000 | UG/KG | 3.7 U | 3.5 U | 3 U | 3.7 U | 3.2 U | 3.2 U | 2.5 U | 2.5 U | 2.5 U |
| TOLUENE | 520,000 | UG/KG | 3.7 U | 3.5 U | 3 U | 3.7 U | 3.2 U | 3.2 U | 0.46 J | 0.3 J | 0.58 J |
| **8081 - ORGANOCHLORINE PESTICIDES** | | | | | | | | | | | |
| GAMMA-BHC (LINDANE) | 420 | UG/KG | 3.3 | 3.4 | 11 | na | 2.2 U | 2.2 U | na | na | na |
| HEPTACHLOR | 99 | UG/KG | 2.5 U | 2.4 U | 2.2 | na | 2.2 U | 2.2 U | na | na | na |
| **8015M - FUEL HYDROCARBONS** | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | 5,000[b] | MG/KG | 23 | 26 | 110 | na | 13 U | 15 | na | na | na |
| **8310 - POLYAROMATIC HYDROCARBONS** | | | | | | | | | | | |
| ACENAPHTHENE | 18,000[b] | UG/KG | na | na | na | na | na | na | na | na | na |
| NAPHTHALENE | 41,000[b] | UG/KG | na | na | na | na | na | na | na | na | na |
| FLUORENE | 1,800,000 | UG/KG | na | na | na | na | na | na | na | na | na |

[a]EPA Region IX Preliminary Remediation Goals (1998)
[b]The values listed for Total Petroleum Hydrocarbons, Acenaphthene and Naphthlene are from the State of Hawaii Department of Health Tier 1 Action Levels (June 1996)
[c]These soil samples were collected in the saturated zone (i.e., below the top of the perched water table)
U - Analyte was not detected above the reported sample quantitation limit
J - The associated value is an estimated quantity
UR - Result is unusable due to not meeting quality control criteria
na - not analyzed
See Appendix A for a summary of all analyses conducted on Kunia Village Area Vadose zone soils
Shading indicates compound was detected in excess of Action Level

TABLE 4-2

COMPOUNDS DETECTED IN VADOSE ZONE SOIL SAMPLES COLLECTED IN THE KUNIA VILLAGE AREA

| | PRGs Soils[a] | Borehole: Depth: Date: | B-39 1 ft 7/29/98 | B-40 1 ft 7/29/98 | B-41 1 ft 7/29/98 | B-41 3 ft 7/29/98 | B-42 1 ft 7/29/98 | B-43 1 ft 7/29/98 | B-43 3 ft 7/29/98 | B-44 1 ft 7/29/98 | B-45 1 ft 7/29/98 | B-45 1 ft Dupl. 7/29/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Residential | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| **8260 - VOLATILE ORGANICS** | | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 4.9 | UG/KG | 0.37 J | 0.37 J | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U |
| 1,2-DICHLOROPROPANE | 340 | UG/KG | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U |
| ETHYLBENZENE | 230,000 | UG/KG | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U |
| TOLUENE | 520,000 | UG/KG | 0.53 J | 0.35 J | 0.67 J | 0.37 J | 0.61 J | 0.32 J | 1.1 J | 0.31 J | 0.53 J | 0.61 |
| **8081 - ORGANOCHLORINE PESTICIDES** | | | | | | | | | | | | |
| GAMMA-BHC (LINDANE) | 420 | UG/KG | 7.95 | na | na | na | na | na | 6.48 | na | na | na |
| HEPTACHLOR | 99 | UG/KG | 2.31 J | na | na | na | na | na | 1.0 U | na | na | na |
| **8015M - FUEL HYDROCARBONS** | | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | 5,000[b] | MG/KG | 2910 J | na | na | na | na | na | 15 | na | na | na |
| **8310 - POLYAROMATIC HYDROCARBONS** | | | | | | | | | | | | |
| ACENAPHTHENE | 18,000[b] | UG/KG | na | na | na | na | na | na | na | na | na | na |
| NAPHTHALENE | 41,000[b] | UG/KG | na | na | na | na | na | na | na | na | na | na |
| FLUORENE | 1,800,000 | UG/KG | na | na | na | na | na | na | na | na | na | na |

[a]EPA Region IX Preliminary Remediation Goals (1998)
[b]The values listed for Total Petroleum Hydrocarbons, Acenaphthene and Naphthlene are from the State of Hawaii Department of Health Tier 1 Action Levels (June 1996)
[c]These soil samples were collected in the saturated zone (i.e., below the top of the perched water table)
U - Analyte was not detected above the reported sample quantitation limit
J - The associated value is an estimated quantity
UR - Result is unusable due to not meeting quality control criteria
na - not analyzed
See Appendix A for a summary of all analyses conducted on Kunia Village Area Vadose zone soils
Shading indicates compound was detected in excess of Action Level

# TREATABILITY INVESTIGATION BOREHOLE SOIL SAMPLING RESULTS
# DEL MONTE CORPORATION (OAHU PLANTATION) SUPERFUND SITE

| Borehole Number: | | TB-1 | | | | TB-2 | | | | | TB-3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth: | | 30 ft | 40 ft | 50 ft | 60 ft | 30 ft | 40 ft | 50 ft | 60 ft | 65 ft | 25 ft | 30 ft | 40 ft | 50 ft | 60 ft | 70 ft |
| Parameter | Units | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. |
| EDB | ug/kg | <2.5 | 0.875 | 47.5 | 149 | <2.5 | 0.52 | 147 | 791 | 3,080 | <2.5 | <2.5 | 2.67 | 80.4 | 3,450 | 305 |
| DBCP | ug/kg | <2.5 | 1.32 | 15.2 | 30.6 | <2.5 | <2.5 | 52.8 | 246 | 1,050 | <2.5 | 23 | 60 | 52.3 | 975 | 483 |
| 1,2-DCP | ug/kg | 7.8 | 4.35 | 33.2 | 50.8 | <2.5 | 1.35 | 102 | 269 | 801 | <2.5 | 20.2 | 90.9 | 136 | 1,050 | 1,440 |
| Toluene | ug/kg | 0.306 | 0.36 J | | | | | | 0.382 | | | 0.317 J | | 1.62 J | 63.8 J | |
| Benzene | ug/kg | | | | | | | 0.803 | 3.0 | | | | | | 52.5 J | |
| 2,3-Dichloro-1-propene | ug/kg | | | | | | | | | | | | | 2.89 | | |

| Borehole Number: | | TB-4 | | | | | | TB-5 | | | TB-6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth: | | 25 ft | 30 ft | 40 ft | 50 ft | 60 ft | 70 ft | 30 ft | 40 ft | 45 ft | 25 ft | 30 ft | 40 ft | 50 ft | 60 ft | 70 ft |
| Parameter | Units | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. |
| EDB | ug/kg | <2.5 | <500 | <2.5 | 5.52 | 3,300 | 2,840 | <2.5 | <500 | <500 | <2.5 | <2.5 | <500 | <500 | <500 | <1000 |
| DBCP | ug/kg | 71.4 | 12,600 | 21.2 | 30.3 | 1,300 | 1,820 | 40.1 | 17,400 | 9,600 | <2.5 | <2.5 | 2,040 | <500 | 966 | 2,910 |
| 1,2-DCP | ug/kg | 15.5 | 3,090 | 86.1 | 89.1 | 1,500 | 1,450 | 8.44 | 4,780 | 2,470 | 32.3 | 36.4 | 901 | 646 | 1,730 | 4,430 |

| Borehole Number: | | TB-7 | | | | | | TB-8 | | TB-9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth: | | 25 ft | 30 ft | 45 ft | 50 ft | 60 ft | 70 ft | 30 ft | 40 ft | 30 ft | 40 ft | 50 ft | 60 ft |
| Parameter | Units | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. | Conc. |
| EDB | ug/kg | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | 101 | 166 |
| DBCP | ug/kg | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | 280 | <2.5 | <2.5 | 52.8 | 109 |
| 1,2-DCP | ug/kg | <2.5 | 0.498 J | <2.5 | <2.5 | 3.85 | 0.528 J | <2.5 | 71.7 | <2.5 | <2.5 | 74.4 | 63.1 |
| Toluene | ug/kg | 0.322 J | | | | | | | | | | | |

Only detected compounds are presented on this table.
Blank Spaces for Toluene, Benzene and 2,3-dichloro-1-propene indicate non-detects
Non-detects for EDB, DBCP and 1,2-DCP are shown as "<" the reporting limit
J - Estimated Value

COMPOUNDS DETECTED IN KUNIA VILLAGE AREA SOIL GAS SAMPLES

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | |
|---|---|---|---|---|---|---|---|
| Borehole Location: | | B-7 | B-8 | B-27 | B-28 | | Calculated[c] |
| Sampling Date: | | 3/26/97 | 3/36/97 | 8/19/97 | 8/19/97 | PRG[a,b] | Ambient Air |
| Sample Depth: | | 11 ft | 11 ft | 11 ft | 11 ft | Ambient Air | Concentration |
| Compound Name | Units | | | | | (PPBv) | |
| 1,1-Dichloroethane | PPBv | nd | nd | nd | 0.89 | 128 | 0.000022 |
| 1,1,1-Trichloroethane | PPBv | 0.8 | nd | nd | nd | 184 | 0.00002 |
| 1,2,4-Trimethylbenzene | PPBv | nd | 1.8 | 2.2 | 4.9 | 1.27 | 0.00012 |
| 1,2-Dichlorobenzene | PPBv | nd | nd | nd | 0.83 | 35.4 | 0.000021 |
| 1,2-Dichloropropane | PPBv | nd | nd | 0.75 | 5.5 | 0.021 | 0.00014 |
| 1,3,5-Trimethylbenzene | PPBv | nd | 0.68 | 0.86 | 1.3 | 1.27 | 0.000022 |
| 1,3-Butadiene | PPBv | nd | 6.1 | 14 | 6.1 | 0.0031 | 0.00035 |
| 1,4-Dioxane | PPBv | nd | 4.6 | 3.4 | 1.7 | 0.17 | 0.00012 |
| 2-Butanone (MEK) | PPBv | 4.8 | 5.6 | 9.2 | 15 | 339 | 0.00038 |
| 2-Propanol | PPBv | nd | 4.2 | 3.9 | nd | | 0.00011 |
| 4-Ethyltoluene | PPBv | nd | nd | nd | 3.3 | | 0.000083 |
| Acetone | PPBv | 8.2 | 12 | 34 | 65 | 156 | 0.0016 |
| Benzene | PPBv | nd | 2 | 4.2 | 4.5 | 0.072 | 0.00011 |
| Bromomethane | PPBv | nd | 1 | nd | nd | 1.34 | 0.000025 |
| Carbon Disulfide | PPBv | nd | nd | 4.1 | 9.2 | 3.21 | 0.00023 |
| Carbon Tetrachloride | PPBv | nd | 1.5 | nd | nd | 0.021 | 0.000038 |
| Chlorobenzene | PPBv | nd | nd | nd | 1.6 | 4.54 | 0.00004 |
| Chloroethane | PPBv | nd | 0.65 | nd | nd | 3791 | 0.000016 |
| Chloroform | PPBv | nd | 0.59 | nd | 0.53 | 0.017 | 0.000015 |
| Chloromethane | PPBv | nd | 1 | nd | nd | 0.53 | 0.000025 |
| Ethanol | PPBv | 2.9 | 7.8 | 8.8 | nd | | 0.00022 |
| Ethyl Benzene | PPBv | nd | 0.87 | 0.77 | 0.56 | 254 | 0.000022 |
| Ethylene Dibromide | PPBv | nd | 0.3 | 0.7 | nd | 0.0011 | 0.000018 |
| Freon 11 | PPBv | 2.4 | 0.27 | 1.2 | 0.34 | 130 | 0.00006 |
| Freon 113 | PPBv | nd | 0.51 | nd | nd | 4053 | 0.000013 |
| Freon 12 | PPBv | 9.9 | 0.76 | 0.63 | 0.65 | 42.4 | 0.00025 |
| Heptane | PPBv | nd | 3.5 | 4.3 | 2.2 | | 0.00011 |
| Hexane | PPBv | nd | 2.8 | 7.4 | 3.2 | 59.7 | 0.00019 |
| m,p-Xylene | PPBv | nd | 1.9 | 3.1 | 2.2 | 168 | 0.000078 |
| o-Xylene | PPBv | nd | 1.5 | 1 | 0.78 | 168 | 0.000038 |
| Propylene | PPBv | 22 | 93 | nd | nd | | 0.0023 |
| Styrene | PPBv | nd | 0.45 | nd | 0.28 | 259 | 0.000011 |
| Trichloroethene | PPBv | 0.92 | nd | nd | nd | 0.21 | 0.000023 |
| Tetrachloroethene | PPBv | 330 J | 1.5 | nd | nd | 0.49 | 0.0083 |
| Toluene | PPBv | nd | 6.4 | 6.8 | 3.2 | 106 | 0.00017 |

a - EPA Region IX Preliminary Remediation Goals for Ambient Air converted to PPBv (August 1996)

b - Blank value means Carcinogenic Potency Factors or Reference Dose values were not found in the literature.

c - Calculated Ambient Air concentration is based on the highest detected soil gas result multiplied by the Natural Mixing Factor of 0.000025.

nd - not detected

COMPOUNDS DETECTED IN KUNIA VILLAGE AREA SURFACE WATER SAMPLES

| | Area: Sample: Date: | Stream Gulch SW-1 03/17/97 | Stream Gulch SW-2 03/17/97 | Stream Gulch SW-3 03/17/97 | Former Fumigant Mixing Area PIT 03/11/97 |
|---|---|---|---|---|---|
| PARAMETER | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | |
| ETHYLENE DIBROMIDE | UG/L | 0.02 U | 0.21 J | 170 D | 167 JD |
| DIBROMOCHLOROPROPANE | UG/L | 0.02 U | 0.02 UR | 0.4 | 0.3 J |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | |
| BROMACIL | UG/L | | 3.3 | | 4.5 |
| 8081 - ORGANOCHLORINE PESTICIDES | | | | | |
| GAMMA-BHC (LINDANE) | UG/L | 0.07 J | 0.05 U | 0.05 U | 0.05 U |

U - Analyte was not detected above the given sample quantitation limit

J - Estimated Value

D - Compound Analyzed from a secondary Analyses

Blank spaces indicates analyte was not tested for in that sample

COMPOUNDS DETECTED IN KUNIA VILLAGE AREA PERCHED GROUNDWATER PIEZOMETERS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | P-1 | P-2 | P-2 Dupl. | P-3 | P-4 | P-5 | P-6 | P-7 | P-8 |
| Sampling Date: | Screening | | 3/25/97 | 3/25/97 | 3/25/97 | 3/25/97 | 3/25/97 | 3/25/97 | 4/14/97 | 4/14/97 | 4/14/97 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.07 | 0.1 | 0.11 | 0.16 | 0.4 J | 3.0 J | 104 D | 1.2 | 11 |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.02 U | 0.12 | 0.029 | 0.02 U | 0.02 UR | 0.08 U | 0.02 U | 0.02 U | 31 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 2.2 | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.5 U | 100 |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 3 | 0.5 U | 0.5 U | 0.5 U | 5 U |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20
MCL - Maximum Contaminant Level (EPA 1996)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary Analyses
UR - Result is unusable due to not meeting quality control criteria
Shading indicates compound was detected in excess of Action Level

TABLE 4-7

COMPOUNDS DETECTED DURING MONITORING WELL HYDROPUNCH SAMPLING IN THE PERCHED GROUNDWATER

| | | Well No.: | MW-1 | | | | | MW-2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth: | 27 ft. | 47 ft. | 70 ft. | 70 ft. | 82-92* ft | 20 ft. | 40 ft. | 62 ft. | 69-79* ft. |
| | | Date: | 05/01/97 | 05/01/97 | 05/05/97 | 05/05/97 Dup | 6/4/97 | 05/14/97 | 05/15/97 | 05/15/97 | 6/4/97 |
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | | | |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 0.087 J | 0.43 J | 3.5 D | 4 D | 0.41 | 41 JD | 1.4 J | 8.1 J | 530 |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 0.02 UJ | 0.022 J | 0.048 | 0.051 | 0.025 | 0.025 J | 0.36 J | 3 | 72 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 1.4 | 3 | 3.1 | 3.6 | 2.4 | 0.5 U | 13 | 43 | 710 *D |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.5 U | 1.3 | 1.1 | 1.3 | 1.3 | 0.5 U | 0.5 U | 0.5 U | 4.9 |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| BENZENE | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 3.5 |
| TOLUENE | 1,000 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 1.1 |
| ETHYLBENZENE | 700 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary Analyses
* - These sample were collected from the completed monitoring well immediately following well development.
Shading indicates the analyte was detected in excess of the Action Level.

TABLE 4-7

COMPOUNDS DETECTED DURING MONITORING WELL HYDROPUNCH SAMPLING IN THE PERCHED GROUNDWATER

| | | Well No.: | MW-3 | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth: Date: | 18 ft. 05/20/97 | 18 ft. 05/20/97 Dup | 33 ft. 05/21/97 | 52 ft. 05/22/97 | 62-72* ft. 6/3/97 |
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 0.02 U | 0.02 U | 48 | 11 D | 1,800 |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 0.65 | 0.7 | 27700 | 350 D | 1,900 |
| 8260 - VOLATILE ORGANICS | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 0.5 U | 0.5 U | 1500 D | 390 D | 6700 *D |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.5 U | 0.5 U | 11 | 1.8 | 0.5 U |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 0.5 U | 0.5 U | 9.6 | 0.5 U | 0.5 U |
| BENZENE | 5 MCL | UG/L | 0.5 U | 0.5 U | 19 | 6 | 74 |
| TOLUENE | 1,000 MCL | UG/L | 0.5 U | 0.5 U | 3.9 | 0.5 U | 0.5 U |
| ETHYLBENZENE | 700 MCL | UG/L | 0.5 U | 0.5 U | 5.7 | 0.5 U | 0.5 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 0.5 U | 0.5 U | 14 | 0.5 U | 0.5 U |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary Analyses
* - These sample were collected from the completed monitoring well immediately following well development.
Shading indicates the analyte was detected in excess of the Action Level.

TABLE 4-8

COMPOUNDS DETECTED IN KUNIA VILLAGE AREA PERCHED GROUNDWATER MONITORING WELLS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | MW-1 | MW-1 | MW-1 | MW-1 | MW-1 | MW-1 | MW-2 | MW-2 | MW-2 | MW-2 | MW-2 | MW-2 |
| Sampling Date: | Screening | | 6/4/97 | 9/8/97 | 10/20/97 | 1/12/98 | 5/12/98 | 7/27/98 | 6/4/97 | 9/8/97 | 10/21/97 | 1/12/98 | 5/13/98 | 7/27/98 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504/8260 - EDB/DBCP[c] | | | | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.41 | 0.39 | 0.63 | 0.52 | 1.1 | 0.65 J | 530 | 570 | 140 J | 108 | 82 | 68 |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.025 | 0.04 U | 0.04 U | 0.02 U | 0.01 U | 0.017 | 72 | 84 | 56 J | 33.8 | 40 | 32.8 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | | | | |
| CIS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.5 U | 25 U | 0.5 U | 1 U | 5 U | 10 U |
| TRANS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.5 U | 25 U | 0.5 U | 1 U | 5 U | 10 U |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 2.4 | 2.4 | 1.8 | 3 | 2.1 | 2.24 | 710 *D | 850 | 530 | 500 D | 880 | 797 |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 1.3 | 1.2 | 0.9 | 1 | 0.97 | 1.21 | 4.9 | 25 U | 4.5 | 4 | 5.4 | 6.09 |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 1 U | 1 U | 0.5 U | 25 U | 0.5 U | 1 U | 10 U | 20 U |
| CARBON TETRACHLORIDE | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U | 0.5 U | 25 U | 0.5 | 1 U | 5 U | 20 U |
| BENZENE | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U | 3.5 | 25 U | 3.6 | 3 | 5 U | 4.69 |
| TOLUENE | 1,000 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U | 1.1 | 25 U | 0.5 U | 1 U | 5 U | 20 U |
| ETHYLBENZENE | 700 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U | 0.5 U | 25 U | 0.5 U | 1 U | 5 U | 20 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 1 U | 1 U | 0.5 U | 25 U | 0.5 U | 1 U | 10 U | 20 U |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | | | | | 0.52 | 0.48 | | | | | 82 | 68 |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | | | | | |
| BROMACIL | 90[a] | UG/L | | 8.5 | 9.5 | 7.8 | 6.7 | 5.8 | | 14 | 14 | 5.4 | 15 J | 12 |
| DIURON | 73 PRG | UG/L | | 0.5 U | 0.5 U | 1 U | 1 U | 1 U | | 0.5 U | 0.97 | 0.82 J | 0.79 J | 0.95 J |
| 8015M - FUEL HYDROCARBONS | | | | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | | UG/L | | 250 U | 370 J | 100 U | 1400 | | | 330 J | 380 J | 160 | 660 U | |
| 8081 - ORGANOCHLORINE PESTICIDES | | | | | | | | | | | | | | |
| HEPTACHLOR | 0.4 MCL | UG/L | | 0.25 U | 0.05 UR | 0.05 UJ | 0.03 U | 0.03 U | | 1 UJ | 0.1 UR | 0.05 UJ | 0.03 U | 0.908 |
| GAMMA-BHC (LINDANE) | 0.2 MCL | UG/L | | 2.1 D | 0.05 UR | 0.05 UJ | 0.04 U | 0.04 U | | 13 J | 4.9 J | 0.05 UJ | 1.4 | 0.82 |
| 8310 - POLYAROMATIC HYDROCARBONS | | | | | | | | | | | | | | |
| ACENAPHTHENE | 320[b] | UG/L | | 0.14 U | 0.14 U | 0.10 U | 0.26 U | | | 0.14 U | 0.14 U | 0.10 U | 0.26 U | |
| NAPHTHALENE | 240[b] | UG/L | | 0.11 U | 0.11 U | 0.10 U | 0.26 U | | | 11 | 0.11 U | 0.10 U | 0.14 | |
| FLUORENE | 13[b] | UG/L | | 0.04 U | 0.04 U | 0.04 U | 0.1 U | | | 0.04 U | 0.11 | 0.092 | 0.1 U | |
| 619 AMETRYN | | | | | | | | | | | | | | |
| AMETRYN | 330 PRG | UG/L | | 1 U | 0.1 UR | 0.1 UR | 0.5 UJ | | | 1 U | 0.1 UR | 0.1 UR | 0.5 J | |

a - EPA Lifetime Health Advisory for drinking water
b - State of Hawaii Dept of Health Tier 1 Action Level (June 1996)
c - EDB/DBCP in MW-2,3,3S,&5 were analyzed by 8260 during 5/98 and 7/98
HI MCL - State of HI Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
PRG are used on this table for compounds which do not have a MCL
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample
MW-3S had insufficient water for sample collection during 7/98 round

U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary analyses
*Outside of quality control limits

Golder Associates

## COMPOUNDS DETECTED IN KUNIA VILLAGE AREA PERCHED GROUNDWATER MONITORING WELLS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | MW-3 | MW-3 | MW-3 | MW-3 | MW-3 | MW-3 | MW-3S | MW-3S Dupl. | MW-3S | MW-3S Dupl. | MW-3S | MW-3S |
| Sampling Date: | Screening | | 6/3/97 | 9/8/97 | 10/22/97 | 1/12/98 | 5/13/98 | 7/28/98 | 9/4/97 | 9/4/97 | 10/22/97 | 10/22/97 | 1/12/98 | 5/13/98 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504/8260 - EDB/DBCP[c] | | | | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 1800 | 3300 | 6800 | 2660 | 3200 | 2900 J | 130 | 130 | 400 U | 400 U | 130 | 100 |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 1900 | 1200 | 1700 | 1060 | 1400 | 1500 | 60000 | 58000 | 78000 D | 81000 D | 45,900 | 47,000 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | | | | |
| CIS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 5 U | 130 U | 0.5 U | 1 U | 25 U | 25 U | 1.2 | 0.5 U | 0.5 U | 0.5 U | 1 U | 100 U |
| TRANS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 5 U | 130 U | 0.5 U | 1 U | 25 U | 25 U | 0.5 U | 1.7 | 0.5 U | 0.5 U | 1 U | 100 U |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 6700 *D | 3700 | 2000 D | 2300 D | 3500 | 2580 | 7100 | 7200 | 5300 D | 5300 D | 5,200 D | 4300 |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 5 U | 130 U | 7.1 | 12 | 25 U | 11.3 J | 25 J | 25 J | 30 D | 30 D | 55 | 100 U |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 5 U | 130 U | 1.5 | 2 | 50 U | 50 U | 0.5 U | 0.5 U | 18 | 18 | 1 U | 200 U |
| CARBON TETRACHLORIDE | 5 MCL | UG/L | 5 U | 130 U | 0.5 U | 1 U | 25 U | 50 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 1 U | 100 U |
| BENZENE | 5 MCL | UG/L | 74 | 130 U | 26 D | 24 | 35 | 32.9 J | 49 J | 54 J | 34 D | 34 D | 61 | 100 U |
| TOLUENE | 1,000 MCL | UG/L | 5 U | 130 U | 0.5 U | 0.6 J | 25 U | 50 U | 6.3 | 6.6 | 5.3 | 5.8 | 7 | 100 U |
| ETHYLBENZENE | 700 MCL | UG/L | 5 U | 130 U | 1.2 | 1 | 25 U | 50 U | 9.1 | 9.4 | 7.7 | 8 | 10 | 100 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 5 U | 130 U | 3.5 | 4 | 50 U | 50 U | 21 | 23 | 27 | 29 | 32 | 200 U |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | | | 2500 D | | 3200 | 1900 | | | 110 D | 110 D | | 100 |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | | | | | |
| BROMACIL | 90[a] | UG/L | | 7.8 | 8.8 | 2 | 7.1 J | 7.2 J | 16 | | 14 | | 1.2 | 6.6 J |
| DIURON | 73 PRG | UG/L | | 0.5 U | 1.3 | 1.0 U | 1.6 | 1 U | 0.5 U | | 0.95 | | 4 | 1 U |
| 8015M - FUEL HYDROCARBONS | | | | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | | UG/L | | 890 | 4300 J | 670 | 2800 | | 18000 | | 2100 J | | 1100 | 8700 |
| 8081 - ORGANOCHLORINE PESTICIDES | | | | | | | | | | | | | | |
| HEPTACHLOR | 0.4 MCL | UG/L | | 0.5 UJ | 0.5 UJ | 0.05 UJ | 0.3 | 0.51 J | 0.05 U | | 5 U | | 5 UJ | 0.03 U |
| GAMMA-BHC (LINDANE) | 0.2 MCL | UG/L | | 1.8 J | 5.8 J | 4.6 J | 10 | 9.33 J | 260 | | 210 | | 210 | 260 |
| 8310 - POLYAROMATIC HYDROCARBONS | | | | | | | | | | | | | | |
| ACENAPHTHENE | 320[b] | UG/L | | 0.14 U | 0.14 UJ | 0.10 U | 0.26 U | | 0.14 U | | 0.71 | | 0.1 U | |
| NAPHTHALENE | 240[b] | UG/L | | 2.2 | 1.7 J | 0.086 J | 0.26 U | | 5.6 | | 4.1 | | 0.33 | |
| FLUORENE | 13[b] | UG/L | | 0.04 U | 0.04 UJ | 0.04 U | 0.1 U | | 0.04 U | | 0.2 | | 0.04 U | |
| 619 AMETRYN | | | | | | | | | | | | | | |
| AMETRYN | 330 PRG | UG/L | | 1 U | 0.1 UJ | 0.1 UR | 0.78 J | | 1 U | | 0.1 UJ | | 0.1 UR | |

a - EPA Lifetime Health Advisory for drinking water
b - State of Hawaii Dept of Health Tier 1 Action Level (June 1996)
c - EDB/DBCP in MW-2,3,3S,&5 were analyzed by 8260 during 5/98 and 7
HI MCL - State of HI Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
PRG are used on this table for compounds which do not have a MCL
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample
MW-3S had insufficient water for sample collection during 7/98 round

U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary analyses
*Outside of quality control limits



Golder Associates

## COMPOUNDS DETECTED IN KUNIA VILLAGE AREA PERCHED GROUNDWATER MONITORING WELLS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | MW-5 | MW-5 | MW-5 | MW-5 | MW-5 | MW-6 | MW-6 | MW-6 | MW-6 | MW-6 |
| Sampling Date: | Screening | | 9/4/97 | 10/23/97 | 1/13/98 | 5/13/98 | 7/28/98 | 10/24/97 | 11/20/97 | 1/13/98 | 5/13/98 | 7/27/98 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504/8260 - EDB/DBCP[c] | | | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 12 | 28 | 15.4 | 20 | 24 J | 0.05 | 0.12 | 0.29 | 0.092 J | 0.18 J |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 160 | 130 | 89.9 | 160 | 260 | 0.04 U | 0.04 U | 0.02 U | 0.008 J | 0.031 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | | |
| CIS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 10 U | 0.5 U | 1 U | 10 U | 5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U |
| TRANS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 10 U | 0.5 U | 1 U | 10 U | 5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 240 | 340 | 370 D | 490 | 524 | 1.9 | 1.9 | 3 | 1.3 | 1.12 |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 10 U | 2.2 | 3 | 10 U | 3.7 | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.414 |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 10 U | 0.5 U | 1 U | 20 U | 10 U | 0.5 U | 0.5 U | 1 U | 1 U | 1 U |
| CARBON TETRACHLORIDE | 5 MCL | UG/L | 10 U | 0.5 U | 1 U | 10 U | 10 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U |
| BENZENE | 5 MCL | UG/L | 10 U | 0.7 | 0.6 J | 10 U | 1.4 J | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U |
| TOLUENE | 1,000 MCL | UG/L | 10 U | 0.5 U | 1 U | 10 U | 10 U | 3.8 | 0.5 U | 1 U | 0.5 U | 1 U |
| ETHYLBENZENE | 700 MCL | UG/L | 10 U | 0.5 U | 1 U | 10 U | 10 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 1 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 10 U | 1.5 | 1 U | 20 U | 2.1 J | 0.5 U | 0.5 U | 1 U | 1 U | 1 U |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | | | | 20 | 23 | | | | 0.5 U | 0.07 J |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | | | |
| BROMACIL | 90[a] | UG/L | | 5.7 | 2.3 | 2.4 J | 5.2 | 19 | 30 | 7.7 | 15 J | 12 |
| DIURON | 73 PRG | UG/L | | 0.5 U | 1 U | 1 U | 1.6 | 2.5 | 4.2 | 1.8 | 1.9 | 1.7 |
| 8015M - FUEL HYDROCARBONS | | | | | | | | | | | | |
| Total Petroleum Hydrocarbons | | UG/L | | 1100 J | 100 UJ | 1300 U | | 1200 | 630 | 330 J | 2200 | |
| 8081 - ORGANOCHLORINE PESTICIDES | | | | | | | | | | | | |
| HEPTACHLOR | 0.4 MCL | UG/L | | 0.15 UR | 0.05 UJ | 0.03 UJ | 0.03 U | 0.05 UJ | 0.05 UJ | 0.05 UJ | 0.03 U | 0.03 U |
| GAMMA-BHC (LINDANE) | 0.2 MCL | UG/L | | 1.8 J | 0.05 UJ | 1.4 | 0.04 U | 0.05 UJ | 0.05 UJ | 0.05 UJ | 0.04 U | 0.04 U |
| 8310 - POLYAROMATIC HYDROCARBONS | | | | | | | | | | | | |
| ACENAPHTHENE | 320[b] | UG/L | | 0.14 U | 0.10 U | 0.26 U | | 0.14 U | 0.14 UJ | 0.10 U | 0.26 U | |
| NAPHTHALENE | 240[b] | UG/L | | 3 J | 0.10 U | 0.26 U | | 0.11 U | 0.11 UJ | 0.10 U | 0.26 U | |
| FLUORENE | 13[b] | UG/L | | 1.1 J | 0.04 U | 0.34 | | 0.15 | 0.04 UJ | 0.04 U | 0.1 U | |
| 619 AMETRYN | | | | | | | | | | | | |
| AMETRYN | 330 PRG | UG/L | | 0.1 UJ | 0.1 UR | 0.5 UJ | | 0.1 UJ | 0.1 U | 0.1 UR | 0.5 UJ | |

a - EPA Lifetime Health Advisory for drinking water
b - State of Hawaii Dept of Health Tier 1 Action Level (June 1996)
c - EDB/DBCP in MW-2,3,3S,&5 were analyzed by 8260 during 5/98 and 7
HI MCL - State of HI Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
PRG are used on this table for compounds which do not have a MCL
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample
MW-3S had insufficient water for sample collection during 7/98 round

U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
D - Compound Analyzed from a secondary analyses
*Outside of quality control limits

Golder Associates

TABLE 4-8

COMPOUNDS DETECTED IN KUNIA VILLAGE AREA PERCHED GROUNDWATER MONITORING WELLS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | |
|---|---|---|---|---|---|---|
| Well No.: | | | Well 9 | Well 9 | Well 9 | Well 9 |
| Sampling Date: | Screening | | 12/15/97 | 1/12/98 | 5/13/98 | 7/28/98 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| **504/8260 - EDB/DBCP[c]** | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.02 U | 0.02 U | 0.39 | 0.84 J |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.031 | 0.02 U | 0.01 J | 0.1 |
| **8260 - VOLATILE ORGANICS** | | | | | | |
| CIS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 0.5 U | 1 U | 0.5 U | 0.5 U |
| TRANS-1,3-DICHLOROPROPENE | 0.081 PRG | UG/L | 0.5 U | 1 U | 0.5 U | 0.5 U |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 0.5 U | 1 U | 0.68 | 1.48 |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.5 U | 1 U | 0.5 U | 1 U |
| 1,1,2-TRICHLOROPROPANE | 30 PRG | UG/L | 0.5 U | 1 U | 1 U | 1 U |
| CARBON TETRACHLORIDE | 5 MCL | UG/L | 0.5 U | 1 U | 0.5 U | 1 U |
| BENZENE | 5 MCL | UG/L | 0.5 U | 1 U | 0.5 U | 1 U |
| TOLUENE | 1,000 MCL | UG/L | 0.5 U | 1 U | 0.5 U | 1 U |
| ETHYLBENZENE | 700 MCL | UG/L | 0.5 U | 1 U | 0.5 U | 1 U |
| XYLENES (TOTAL) | 10,000 MCL | UG/L | 0.5 U | 1 U | 1 U | 1 U |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | | | 0.5 U | 0.6 |
| **632 - CARBAMATES & UREA PESTICIDES** | | | | | | |
| BROMACIL | 90[a] | UG/L | 0.94 | 0.71 J | 0.80 J | 2 U |
| DIURON | 73 PRG | UG/L | 1 U | 1 U | 0.48 J | 0.52 J |
| **8015M - FUEL HYDROCARBONS** | | | | | | |
| Total Petroleum Hydrocarbons | | UG/L | 100 U | 100 U | 350 U | |
| **8081 - ORGANOCHLORINE PESTICIDES** | | | | | | |
| HEPTACHLOR | 0.4 MCL | UG/L | 0.05 U | 0.05 UJ | 0.03 U | 0.03 U |
| GAMMA-BHC (LINDANE) | 0.2 MCL | UG/L | 0.05 U | 0.05 UJ | 0.04 U | 0.04 U |
| **8310 - POLYAROMATIC HYDROCARBONS** | | | | | | |
| ACENAPHTHENE | 320[b] | UG/L | 0.1 U | 0.10 U | 0.26 U | |
| NAPHTHALENE | 240[b] | UG/L | 0.1 U | 0.10 U | 0.26 U | |
| FLUORENE | 13[b] | UG/L | 0.04 U | 0.04 U | 0.1 U | |
| **619 AMETRYN** | | | | | | |
| AMETRYN | 330 PRG | UG/L | 0.1 U | 0.39 J | 0.5 UJ | |

a - EPA Lifetime Health Advisory for drinking water
b - State of Hawaii Dept of Health Tier 1 Action Level (June 1996)
c - EDB/DBCP in MW-2,3,3S,&5 were analyzed by 8260 during 5/98 and 7
HI MCL - State of HI Administrative Rule Title 11, Chapter 11-20.
MCL - Maximum Contaminant Level (EPA 1996)
PRG - EPA Region IX Preliminary Remediation Goals Tap Water (1998)
PRG are used on this table for compounds which do not have a MCL
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample
MW-3S had insufficient water for sample collection during 7/98 round

# COMPARISON OF COMPOUNDS DETECTED IN RI GROUNDWATER SAMPLES TO SPLIT SAMPLES COLLECTED BY EPA

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | RI Results | EPA Results | RI Results | EPA Results | RI Results | EPA Results |
|---|---|---|---|---|---|---|---|---|
| Well No.: | | | MW-6 | MW-6 | Basal Well | Basal Well | Kunia Well | Kunia Well |
| Sampling Date: | Screening | | 11/20/97 | 11/20/97 | 11/20/97 | 11/20/97 | 11/24/97 | 11/24/97 |
| PARAMETER | Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504/8260 - EDB/DBCP | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.12 | 0.16 | 0.14 | 0.09 | 0.22J | 0.15 |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.04 U | 0.02 J | 0.93 | 0.61 | 1.4 J | 0.82 |
| 8260 - VOLATILE ORGANICS | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 1.9 | NA | 0.5 U | NA | 0.5 | 0.7 J |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.5 U | NA | 0.5 U | NA | 0.7 | 0.9 J |
| TRICHLOROETHYLENE | 5 MCL | UG/L | 0.5 U | NA | 0.5 U | NA | 0.5 U | 0.5 J |
| 8015M - FUEL HYDROCARBONS | | | | | | | | |
| Total Petroleum Hydrocarbons | | UG/L | 630 | 500 | 100 U | 250 BJ | 100 U | 390 U |

This table only presents compounds which were detected. Appendix K presents the results for all of the analyses performed on the split samples.

HI MCL - State of HI Administrative Rule Title 11, Chapter 11-20.

MCL - Maximum Contaminant Level (EPA 1996)

Shading indicates compound was detected in excess of Action Level

NA - EPA laboratory results were not available for these compounds

U - Analyte was not detected above the given sample quantitation limit

J - Estimated Value

B - Total Petroleum Hydrocarbons were also detected in the EPA field blank at 250 ug/L and in their method blank at 240 ug/L.

COMPOUNDS DETECTED DURING VERTICAL PROFILE GROUNDWATER SAMPLING OF THE KUNIA WELL

| | | Depth: Date: | 827ft. 03/15/97 | 837ft. 03/16/97 | 847ft. 03/16/97 | 857ft. 03/16/97 | 867ft. 03/16/97 | 877ft. 03/16/97 | 877ft. 03/16/97 Dup | 887ft. 03/16/97 | 897ft. 03/16/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 0.02 UJ | 0.93 | 0.9 | 0.97 | 1 | 1 | 0.98 | 1 | 0.95 |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 0.74 J | 1.6 | 1.6 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 0.5 U | 1.7 | 1.8 | 1.7 | 3 | 3.9 | 3.9 | 2 | 2 |
| CADMIUM | 0.005 MCL | MG/L | 0.0006 | | | | | | | | |
| LEAD | 0.015 MCL | MG/L | 0.008 | | | | | | | | |

| | | Depth: Date: | 907ft. 03/16/97 | 917ft. 03/16/97 | 927ft. 03/16/97 | 937ft. 03/16/97 | 947ft. 03/16/97 | 957ft. 03/16/97 | 967ft. 03/16/97 |
|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 1.1 | 1 | 0.79 | 0.41 | 0.82 | 0.87 | 0.87 |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 1.5 | 1.5 | 1.2 | 0.65 | 1.4 | 1.4 | 1.6 |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 2.4 | 2.3 | 2.5 | 1.1 | 2.3 | 4.6 | 4 |
| CADMIUM | 0.005 MCL | MG/L | | | | | | | |
| LEAD | 0.015 MCL | MG/L | | | | | | | |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20

MCL - Maximum Contaminant Level (EPA 1996)

U - Analyte was not detected above the given sample quantitation limit

J - Estimated Value

Shading indicates the analyte was detected in excess of the Action Level

Blank spaces indicates analyte was not tested for in that sample

COMPOUNDS DETECTED DURING MISCELLANEOUS PUMPING OF THE KUNIA WELL

| | | Date: Time: | Start of Purge 03/12/97 12:13 | End of Purge 03/12/97 13:14 | Start of Pump Test 10/18/97 09:45 | 10/18/97 10:45 | 10/18/97 11:45 | 10/18/97 12:45 | 10/19/97 09:45 | End of Pump Test 10/20/97 07:30 |
|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | | |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 0.99 J | 0.46 J | 0.17 J | 0.11 J | 0.09 J | 0.05 J | 0.04 UJ | 0.04 U |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 1.7 J | 1.2 J | 1 J | 0.96 J | 0.97 J | 0.84 J | 0.91 J | 0.92 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | | | 0.6 | 0.7 | 0.7 | 0.7 | 0.6 | 0.5 U |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | | | 0.9 | 0.6 | 0.9 | 1 | 1 | 0.7 |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20
MCL - Maximum Contaminant Level (EPA 1996)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
Blank spaces indicates analyte was not tested for in that sample
Shading indicates the analyte was detected in excess of the Action Level

| | | Date: Time: | Start of Pump Test 11/14/97 09:30 | 11/14/97 13:00 | 11/15/97 09:00 | End of Pump Test 11/16/97 09:00 |
|---|---|---|---|---|---|---|
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | |
| Ethylene Dibromide (EDB) | 0.04 HI MCL | UG/L | 0.15 | 0.19 | 0.16 | 0.17 |
| Dibromochloropropane (DBCP) | 0.04 HI MCL | UG/L | 0.79 | 1.2 | 1.1 | 1.1 |
| 8260 - VOLATILE ORGANICS | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | | | | |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | | | | |

HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20
MCL - Maximum Contaminant Level (EPA 1996)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
Blank spaces indicates analyte was not tested for in that sample
Shading indicates the analyte was detected in excess of the Action Level



Golder Associates

# COMPOUNDS DETECTED IN KUNIA VILLAGE AREA BASAL GROUNDWATER WELLS

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | Kunia Well[b] | Kunia Well[b] Dupl. | Kunia Well | Kunia Well | Kunia Well | Kunia Well | Kunia Well |
| Sampling Date: | | | 10/20/97 | 10/20/97 | 11/24/97 | 12/15/97 | 1/12/98 | 5/11/98 | 7/27/98 |
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.04 U | 0.06 | 0.22 J | 0.13 | 0.16 | 0.16 | 0.21 J |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.92 | 1.1 | 1.4 J | 0.7 | 0.73 | 0.89 | 0.64 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 | 0.5 U | 1 U | 0.5 U | 0.46 |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.7 | 0.5 U | 0.9 | 0.9 | 1 | 0.86 | 0.80 |
| Trichloroethylene | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.27 J* |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | |
| BROMACIL | 90[a] | UG/L | 2 | na | 2 | 1.83 | 1.8 | 1.5 | 1.2 |

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Well No.: | | | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 | Basal Well 2703-02 |
| Sampling Date: | | | 10/23/97 | 11/20/97 | 12/16/97 | 1/13/98 | 5/12/98 | 5/12/98 Dup. | 7/27/98 | 7/27/98 Dup. |
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | | |
| ETHYLENE DIBROMIDE | 0.04 HI MCL | UG/L | 0.1 | 0.14 | 0.11 | 0.14 | 0.26 | 0.26 | 0.15 J | 0.16 J |
| DIBROMOCHLOROPROPANE | 0.04 HI MCL | UG/L | 0.66 | 0.93 | 0.7 | 0.84 | 0.74 | 0.75 | 0.86 | 0.90 |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | |
| 1,2-DICHLOROPROPANE | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.51 | 0.52 | 0.53 J | 0.53 J |
| 1,2,3-TRICHLOROPROPANE | 0.8 HI MCL | UG/L | 0.7 | 0.5 U | 0.7 | 0.8 J | 0.54 | 0.61 | 0.57 J | 0.62 J |
| Trichloroethylene | 5 MCL | UG/L | 0.5 U | 0.5 U | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.26 J* | 0.25 J* |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | |
| BROMACIL | 90[a] | UG/L | 1.8 | 3.2 | 2.15 | 1.9 | 1.3 | 1.6 | 1.3 | 1.6 |

a - EPA Lifetime Health Advisory for drinking water
b - Sample represents last sample collected at the end of Oct 18-20 pumping test (See Table 4-9)
HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20
MCL - Maximum Contaminant Level (EPA 1996)

U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
J* - Trichloroethene was also detected in the Trip Blank associated with the 7/98 sampling
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample



Golder Associates

REGIONAL BASAL GROUNDWATER WELLS ANALYTICAL RESULTS[a]

| Well Name: Sampling Date: | | | Country Club 11/05/97 | Country Club 2/17/98 | Country Club 5/11/98 | Country Club 7/98 | Navy Well 10/22/97 | Navy Well 01/12/98 | Navy Well 5/12/98 | Navy Well 7/28/98 | Honou-liuli (2303-03) 5/11/98 | Honou-liuli (2303-03) 7/98 | Waikaka-laua ST12MW05 01/12/98 | Waikaka-laua ST12MW05 1/12/98 Dup. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Screening Level | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 504 - EDB/DBCP | | | | | | | | | | | | | | |
| Ethylene Dibromide | 0.04 HI | UG/L | 0.04 U | 0.02 U | 0.02 | 0.02 | 0.04 U | 0.02 U | 0.02 U | 0.02 UJ | 0.02 U | 0.02 U | 0.02 UJ | 0.02 UJ |
| Dibromochloropropane | 0.04 HI | UG/L | 0.04 U | 0.038 | 0.071 | 0.059 | 0.04 U | 0.02 U | 0.01 U | 0.01 U | 0.01 U | 0.01 U | 0.02 UJ | 0.02 UJ |
| 8260 - VOLATILE ORGANICS | | | | | | | | | | | | | | |
| 1,2-Dichloropropane | 5 MCL | UG/L | 0.5 U | 1 U | 1 U | 0.143 J | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.5 U | 1 U | 1 U | 1 U |
| 1,2,3-Trichloroproprane | 0.8 HI MCL | UG/L | 0.5 U | 1 U | 1 U | 0.216 J | 0.5 U | 1 U | 0.5 U | 0.5 U | 0.5 U | 1 U | 1 U | 1 U |
| Trichloroethylene | 5 MCL | UG/L | 0.5 U | 1 U | 1 U | 1 U | 2.8 | 3 | 2.8 | 2.65 | 0.5 U | 1 U | 0.5 J | 1 U |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | | | | | |
| Bromacil | 90[b] | UG/L | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |

a - For comparison purposes, this table provides the Regional Basal Well analytical results for compounds that were detected in the Kunia Village Area Wells
b - EPA Lifetime Health Advisory for drinking water
HI MCL - State of Hawaii Administrative Rule Title 11, Chapter 11-20
MCL - Maximum Contaminant Level (EPA 1996)
U - Analyte was not detected above the given sample quantitation limit
J - Estimated Value
na - Not Analyzed
Shading indicates compound was detected in excess of Action Level

COMPOUNDS DETECTED IN SOIL SAMPLES FROM EMPTY DRUM BURIAL SITES

| | PRG Soils[a] | Area: | Field 60 Location 1 | Field 60 Location 1 | Field 60 Location 1 | Field 60 Location 2 | Field 60 Location 2 | Field 60 Location 3 | Field 60 Location 3 | Field 90 | Behind Poamoho Crateyard |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Borehole: | B-1 | B-2 | B-3 | B-2 | B-3 | B-3 | B-3 | B-3 | B-1 |
| | | Depth: | 12.5ft. | 16ft. | 13ft. | 13ft. | 7.5ft. | 9ft. | 14ft. | 9.5ft. | 14ft. |
| | | Date: | 04/02/97 | 04/02/97 | 04/02/97 | 05/14/98 | 05/14/98 | 05/14/98 | 05/14/98 | 04/03/97 | 04/01/97 |
| PARAMETER | Residential | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 632 - CARBAMATES & UREA PESTICIDES | | | | | | | | | | | |
| BROMACIL | 850,000 | UG/KG | 110 U | 570 | 250 | 130 J | 270 | 260 U | 260 U | 110 U | 110 U |
| 8081 - ORGANOCHLORINE PESTICIDES | | | | | | | | | | | |
| GAMMA-BHC (LINDANE) | 420 | UG/KG | 3.7 | 2.3 U | 2.3 U | 1.3 U | 2.7 | 6.5 | 20 | 2.2 U | 2.3 U |
| HEPTACHLOR | 99 | UG/KG | 2.2 U | 2.3 U | 2.3 U | 55 | 73 | 0.99 U | 0.99 U | 6 | 2.3 |
| 619 AMETRYN | | | | | | | | | | | |
| AMETRYN | 490,000 | UG/KG | 43 U | 45 U | 44 U | 1700 J | 1800 J | 260 U | 270 U | 42 U | 44 U |
| 8015M - FUEL HYDROCARBONS | | | | | | | | | | | |
| TPH-Diesel | 5,000 | MG/KG | 13 U | | | | | | 32 | 13 U | |

a - EPA Region IX Preliminary Remediation Goals (1998)
IRIS does not include a RfD for Bromacil. Therefore, the soil PRG is based on toxicity data for Terbacil as a surrogate
U - Analyte was not detected above the reported sample quantitation limit

COMPOUNDS DETECTED IN SOIL GAS SAMPLES FROM THE
EMPTY DRUM BURIAL SITE BEHIND THE POAMOHO CRATEYARD

| Del Monte Corporation (Oahu Plantation) Superfund Site | | | | | | |
|---|---|---|---|---|---|---|
| | Borehole Location: | B-1 | B-2 | B-3 | | |
| | Sampling Date: | 4/1/97 | 4/1/97 | 4/1/97 | PRG[a,b] | Calculated[c] |
| | Sample Depth: | 6 ft | 6 ft | 7 ft | Ambient Air | Ambient Air |
| Compound Name | Units | | | | (PPBv) | Concentration |
| 1,2,4-Trimethylbenzene | PPBv | 0.92 | 0.93 | 6.1 | 1.27 | 0.00015 |
| 1,3,5-Trimethylbenzene | PPBv | nd | 0.31 | 1.8 | 1.27 | 0.000045 |
| 1,3-Butadiene | PPBv | 6.7 | 3.4 | nd | 0.0312 | 0.00017 |
| 1,4-Dichlorobenzene | PPBv | 1.6 | nd | nd | 6.15 | 0.00004 |
| 1,4-Dioxane | PPBv | nd | 0.96 | nd | 0.169 | 0.000024 |
| 2-Butanone (MEK) | PPBv | 13 | 12 | 3 | 339 | 0.00033 |
| 2-Hexanone | PPBv | nd | 2 | nd | | 0.00005 |
| 2-Propanol | PPBv | nd | 0.84 | 0.82 | | 0.000021 |
| 4-Ethyltoluene | PPBv | nd | nd | 3.4 | | 0.000085 |
| Acetone | PPBv | 28 | 26 | 7.3 | 156 | 0.0007 |
| Benzene | PPBv | 3 | 1.8 | 9.8 | 0.072 | 0.00025 |
| Bromomethane | PPBv | nd | 0.42 | nd | 1.34 | 0.000011 |
| Chlorobenzene | PPBv | 0.94 | nd | nd | 4.54 | 0.000024 |
| Chloroethane | PPBv | nd | 0.41 | 0.33 | 3,791 | 0.000010 |
| Chloroform | PPBv | nd | 0.71 | nd | 0.0173 | 0.000018 |
| Chloromethane | PPBv | 1.2 | 0.81 | 0.7 | 0.533 | 0.00003 |
| Cyclohexane | PPBv | nd | nd | 4.7 | | 0.00012 |
| Ethanol | PPBv | 11 | 7.4 | 4.4 | | 0.00028 |
| Ethyl Benzene | PPBv | 0.75 | 0.65 | 5.3 | 254 | 0.00013 |
| Freon 11 | PPBv | nd | 0.3 | 0.29 | 130 | 0.0000075 |
| Freon 113 | PPBv | nd | 0.23 | 0.18 | 4053 | 0.0000058 |
| Freon 12 | PPBv | 0.65 | 0.77 | 0.74 | 42.4 | 0.000019 |
| Heptane | PPBv | nd | 2.2 | 6.8 | | 0.00017 |
| Hexane | PPBv | nd | 4.2 | 10 | 59.7 | 0.00025 |
| m,p-Xylene | PPBv | 1.4 | 1.2 | 13 | 168 | 0.00033 |
| o-Xylene | PPBv | 1.1 | 1.1 | 12 | 168 | 0.0003 |
| Styrene | PPBv | nd | 0.32 | nd | 259 | 0.000008 |
| Tetrachloroethene | PPBv | nd | 0.26 | nd | 0.486 | 0.0000065 |
| Toluene | PPBv | 5.5 | 4.4 | 52 | 106 | 0.0013 |

a - EPA Region IX Preliminary Remediation Goals for Ambient Air converted to PPBv (August 1996)

b - Blank value means Carcinogenic Potency Factors or Reference Dose values were not found in the literature

c - Calculated Ambient Air concentration is based on the highest detected soil gas result multiplied by the Natural Mixing Factor of 0.000025

nd - not detected

COMPOUNDS DETECTED IN SOIL SAMPLES FROM FORMER UNDERGROUND STORAGE TANK SITES

| | | Borehole: | Field 9 B-1 | Field 9 B-1 | Field 9 B-1 | Field 9 B-1 |
|---|---|---|---|---|---|---|
| | | Depth: | 11ft. | 16ft. | 21ft. | 25ft. |
| | | Date: | 04/04/97 | 04/04/97 | 04/04/97 | 04/04/97 |
| PARAMETER | Tier 1 Action Level[a] | UNITS | Conc. Q | Conc. Q | Conc. Q | Conc. Q |
| 8015M - FUEL HYDROCARBONS | | | | | | |
| TOTAL PETROLEUM HYDROCARBONS | 5,000 | MG/KG | 18 | 8600 | 1300 | 6400 |
| LEAD | 400 | MG/KG | | 2 | 2 | 2.2 |
| 8310 - POLYAROMATIC HYDROCARBONS | | | | | | |
| ACENAPHTHENE | 18,000 | UG/KG | | 190 J | 55 J | 120 J |
| NAPHTHALENE | 41,000 | UG/KG | | 660 J | 340 J | 270 J |
| FLUORENE | 1,800,000[b] | UG/KG | | 1400 J | 470 J | 890 J |

a - State of Hawaii Department of Health Tier 1 Action Levels (June 1996)
b - EPA Region IX Residential Soil PRG
NA - Action level is not available for Fluorene
J - Estimated value
Shading indicates compound was detected in excess of Action Level
Blank spaces indicates analyte was not tested for in that sample

TABLE 5-1

PHYSICAL AND CHEMICAL PROPERTIES OF EDB, DBCP, AND TCP

| Chemical CAS Registry Number | Molecular Formula | Molecular Weight [3] | Boiling Point [3] (°C) | Melting Point [3] (°C) | Vapour Pressure [3] (mm Hg) | Henry's Law Const. [3] Kh (atm-m³/mole) | Solubility in water [3] So (mg/l) | Org. C to Water part. coeff. Koc (mL/g) | Octanol to water part. coeff log Kow [3] | $t_{1/2}$ (years) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ethylene Dibromide | $C_2H_4Br_2$ | 187.88 | 131-132 | 9.8 | 11.2 @ 25°C | 6.67 x 10-4 | 4,150 @ 25°C | 14-160 [3] | 1.93 | 14 [1] | hydrolysis in MA aquifer |
| (EDB) | | | | | | | | < 83 [1] | | 8 - 13.2 [3] | hydrolysis @ pH 7 and 20°C |
| 106-93-4 | | | | | | | | 5.7 [2] | | 2.5 [3] | hydrolysis @ pH 7.5 and 25°C |
| | | | | | | | | | | 273 [3] | hydrolysis @ pH 10 |
| | | | | | | | | | | 2.2 - 15 [1] | hydrolysis @ 15°C |
| | | | | | | | | | | 8 [1] | hydrolysis @ 20°C |
| | | | | | | | | | | 1.5 - 2 [1] | hydrolysis @ 22°C |
| | | | | | | | | | | 2.5 - 4.1 [1] | hydrolysis @ 25°C |
| | | | | | | | | | | | |
| 1,2-Dibromo-3-Chloropropane | $C_3H_5Br_2Cl$ | 236.36 | 196 | 6 | 0.58 @ 20°C | 1.47 x 10-4 | 1,230 @ 20°C | 148 [3] | 2.26 | 38 [7] | Estimated hydrolysis in Oahu aquifer |
| (DBCP) | | | | | | | | 20-129 [4] | | 0.4 [4] | hydrolysis @ pH 9 and 25°C |
| 96-12-8 | | | | | | | | 30 [2] | | 6.1 [6] | hydrolysis in Calif. gw, pH 7.8, 21.1°C |
| | | | | | | | | 32 [5] | | 141 [4] | hydrolysis @ pH 7 and 15°C |
| | | | | | | | | | | 38 [4] | hydrolysis @ pH 7 and 25°C |
| | | | | | | | | | | | |
| 1,2,3-Trichloropropane | $C_3H_5Cl_3$ | 147.43 | 156.8 | -14.7 | 3.1 @ 25°C | 3.44 x 10-4 | 1,750 @ 25°C | 72 - 98 [4] | 1.98 | 44 [4] | hydrolysis @ pH 7.5 and 25°C |
| (TCP) | | | | | | | | 7.8 [2] | | | |
| | | | | | | | | | | | |

Notes:

1 Pignatello and Cohen, 1990.
2 Loague et al, 1989.
3 Sage et al, 1989.
4 Syracuse Research Corp., 1980.
5 Orr and Lau, 1987.
6 Deeley et al, 1991.
7 Lau, 1987.

ESTIMATED MIXING ZONE DEPTH

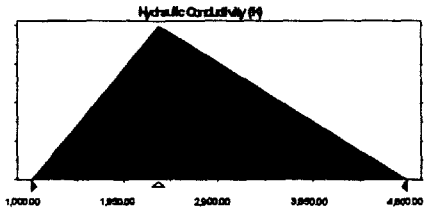
| Assumed Rate of Infiltration[a], $ft^3/yr$ | Basal Hydraulic Conductivity[b], ft/day | Basal Hydraulic Conductivity, ft/year | Basal Hydraulic Gradient[b] | Mixing Zone Width, ft | Required Thickness[c], ft |
|---|---|---|---|---|---|
| A | | B | C | D | =A/(B*C*D) |
| 2 | 1000 | 365000 | 1.27E-04 | 1.0 | 0.04 |
| 5 | | | | 1.0 | 0.11 |
| 10 | | | | 1.0 | 0.22 |

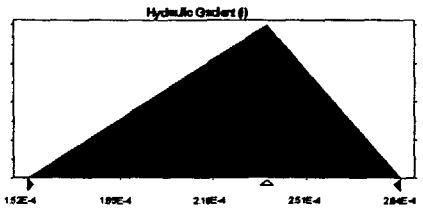
[a] - Infiltration from surface (per unit area) through the perched aquifer to the basal aquifer.
[b] - Low estimated values. Chosen to maximize the thickness calculation.
[c] - Basal aquifer saturated thickness required to convey infiltrating water laterally in the basal aquifer.

PROBABILISTIC ESTIMATE OF TRAVEL TIMES TO DOWNGRADIENT WELLS

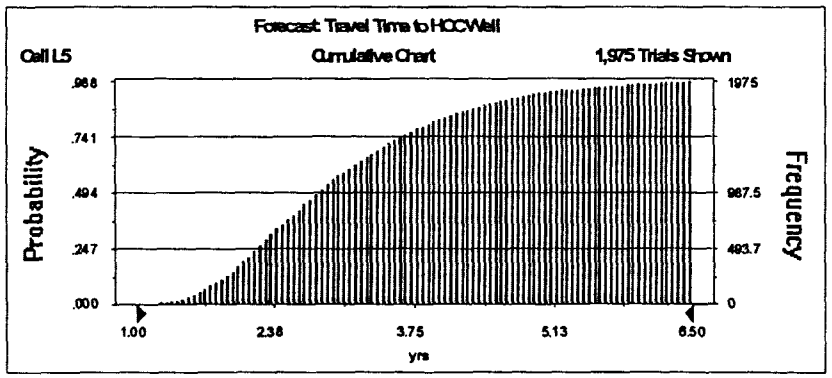
| WELL | Hydraulic Conductivity (K), ft/day | | | gradient (i), ft/ft | | | Effective Porosity (n) | | | travel distance (x), ft | travel time, years |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Most Likely | Max | Min | Most Likely | Max | Min | Most Likely | Max | | |
| HCC well | 1000 | 2300 | 4800 | 1.52E-04 | 2.37E-04 | 2.84E-04 | 0.05 | 0.075 | 0.1 | 8000 | =x/(Ki/n) |
| Honouliuli Wells | 1000 | 2300 | 4800 | 1.52E-04 | 2.37E-04 | 2.84E-04 | 0.05 | 0.075 | 0.1 | 23400 | =x/(Ki/n) |

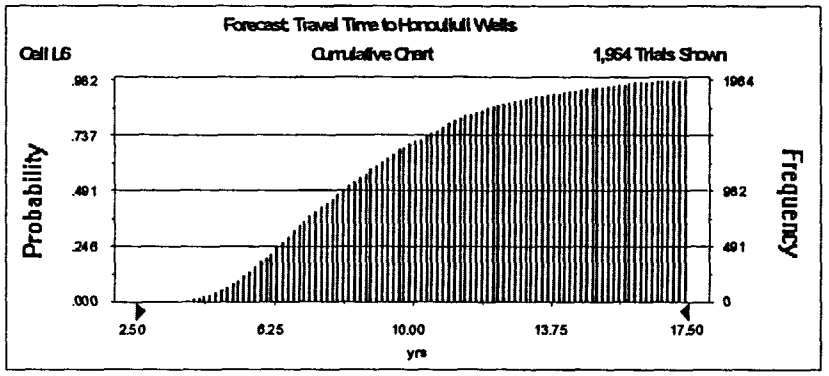
**ASSUMED PROBABILITY DISTRIBUTIONS:**



**RESULTS:**




| Percentile | yrs (approx.) |
|---|---|
| 0% | 1.07 |
| 5% | 1.64 |
| 25% | 2.23 |
| 50% | 2.85 |
| 75% | 3.69 |
| 95% | 5.25 |
| 100% | 8.77 |

| Percentile | yrs (approx.) |
|---|---|
| 0% | 3.09 |
| 5% | 4.86 |
| 25% | 6.45 |
| 50% | 8.23 |
| 75% | 10.67 |
| 95% | 15.08 |
| 100% | 33.41 |

Golder Associates

ESTIMATED IMPACTS OF THE PERCHED AQUIFER ON BASAL AQUIFER WATER QUALITY

| DBCP Mass Balance Calculation for Impact of Perched Aquifer on Basal Aquifer (Assuming No Degradation) | | | | | | |
|---|---|---|---|---|---|---|
| Concentration[a], µg/L | Area[b], $ft^2$ | Net Area[c], $ft^2$ | Vertical Flux[d], $ft^3/yr$ | Vertical Flux, L/yr | Mass Flux, µg/yr | |
| 50 | 14,020 | 5,635 | 2,818 | 78,186 | 3,909,281 | |
| 500 | 8,385 | 6,564 | 3,282 | 91,076 | 45,537,750 | |
| 2395 | 1,821 | 1,821 | 911 | 25,266 | 60,512,968 | |
| | | | | Total mass, µg/yr | 109,959,999 | |
| **EDB Mass Balance Calculation for Impact of Perched Aquifer on Basal Aquifer (Assuming No Degradation)** | | | | | | |
| Concentration[a], µg/L | Area[b], $ft^2$ | Net Area[c], $ft^2$ | Vertical Flux[d], $ft^3/yr$ | Vertical Flux, L/yr | Mass Flux, µg/yr | |
| 0.5 | 92,252 | 47,755 | 23,900 | 663,225 | 331,613 | |
| 5 | 44,497 | 25,874 | 12,900 | 357,975 | 1,789,875 | |
| 50 | 18,623 | 11,273 | 5,600 | 155,400 | 7,770,000 | |
| 500 | 7,350 | 5,320 | 2,700 | 74,925 | 37,462,500 | |
| 3870 | 2,030 | 2,030 | 1,000 | 27,750 | 107,392,500 | |
| | | | | Total mass, µg/yr | 154,746,488 | |
| **Resulting Concentration in Basal Aquifer (Assuming No Degradation)** | | | | | | |
| Hydraulic Conductivity[e] (ft/yr) | Gradient[f] (ft/ft) | Cross-Sectional Area[g], $ft^2$ | Horizontal Flux, $ft^3/yr$ | Horizontal Flux, L/yr | Basal Aquifer Conc[h], µg/L | |
| 839500 | 0.000236742 | 4,000 | 790,000 | 22,515,000 | 5 | DBCP |
| | | | | | 7 | EDB |

[a] - Average concentrations at the base of the perched aquifer within the contours shown in Figures 5-2 and 5-3. Includes monitoring well data collected through Jan-98 and estimated concentrations from soil data.
[b] - Total area enclosed within each contour.
[c] - Net area of each contour.
[d] - Assuming 6 in per year infiltration.
[e] - Assumes 2300 ft/day.
[f] - Assumes 1.25 ft/mile.
[g] - Assumes source 400 ft wide by 10 ft deep.
[h] - Resulting from the total mass flux of chemical divided by basal aquifer flux.

TABLE 5-5

SUMMARY OF MODELING INPUT PARAMETERS/APPROACHES

| Modeling Scenario | Software | Approach/Inputs | Chemicals Modeled | Source Concentration | Input Parameters | | | | | | | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Source Width, ft | Source Thickness, ft | Basal Hydraulic Conductivity, ft/yr | Porosity | Hydraulic Gradient, ft/mile | Dispersivity, ft | Solute Half-Life, years | |
| Present to Future (1997-Future) Case 1 | BIOSCREEN (Modified) | Probabilistic | EDB<br>DBCP<br>TCP<br>DCP | Based on vertical profiling results; Used average concentrations from vertical profiling; Multiplied average concentration by factor of 2. Constant source concentration. | 400 | 1-10 (5) | 1000-3500 (2300) | .05-.1 (.075) | .67-1.5 (1) | $a_x$=100-250 (150)<br>$a_y$=.1$a_x$, $a_z$=0.05$a_x$ | EDB - 2 -15 (10)<br>DBCP - 5 - 40 (20)<br>TCP - 5 - 40 (20)<br>DCP - 5 - 40 (20) | 90th Percentile of Distances to MCL |
| Past to Present (1980-1997) Case 2 | BIOSCREEN | Deterministic, using reasonable worst case, reasonable best case, and reasonable average case scenarios | EDB<br>DBCP | Historical data (for end of Kunia Well pumping) for the period 1980-1997; Adjusted upwards by factor of 10 for EDB and 3 for DBCP; Data fitted to a first-order decay function | 300 | 10 | Assumed constant velocity of 1500 ft/yr | - | - | Average Case - $a_x$=150<br>Worst Case - $a_x$=100<br>Best Case - $a_x$=200<br>All Cases - $a_y$=.1$a_x$, $a_z$=0.05$a_x$ | Average Case - $t_{1/2}$=10/20 for EDB/DBCP Worst Case t1/2=15/40 for EDB/DBCP<br>Best Case - t1/2=2/10 for EDB/DBCP | Distance to MCL |

Probabilistic inputs presented as a range from minimum to maximum with the best esimate in parenthesis.

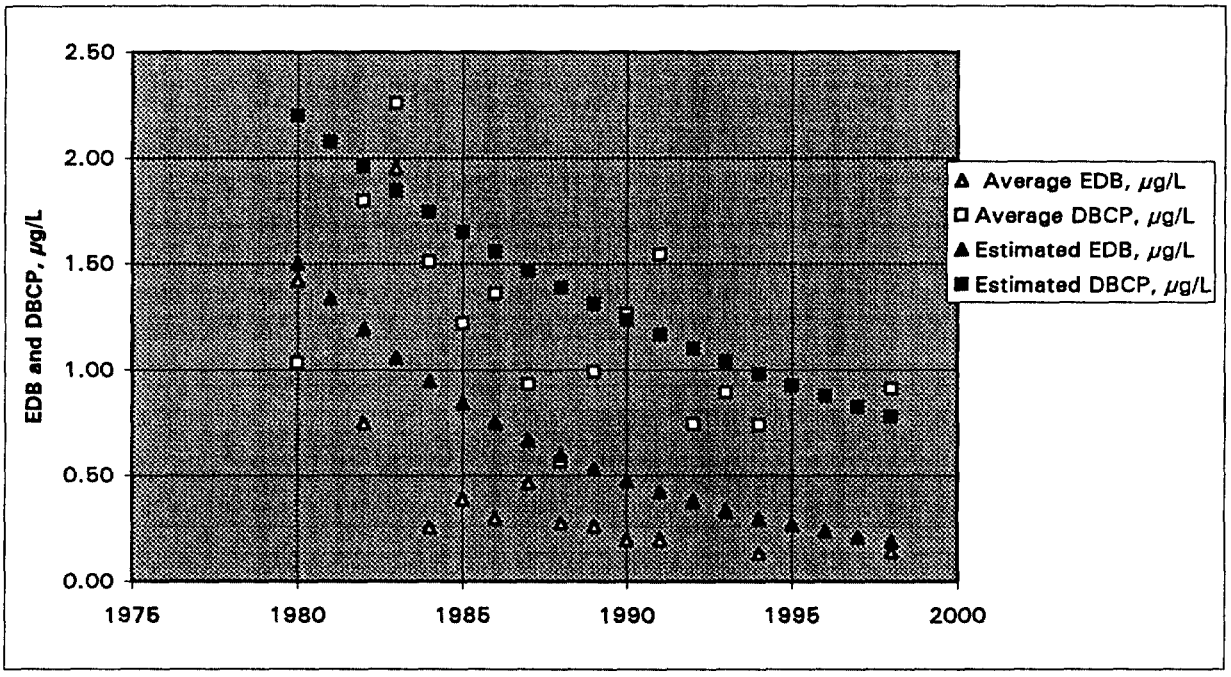
SOURCE CONCENTRATIONS VS TIME
(KUNIA WELL AVERAGE CONCENTRATIONS AT END OF PUMPING)

| Year | Average EDB, µg/L | Average DBCP, µg/L | Estimated EDB, µg/L | Estimated DBCP, µg/L |
|---|---|---|---|---|
| 1980 | 1.42 | 1.03 | 1.50 | 2.20 |
| 1981 | | | 1.34 | 2.08 |
| 1982 | 0.75 | 1.80 | 1.19 | 1.96 |
| 1983 | 1.95 | 2.26 | 1.06 | 1.85 |
| 1984 | 0.25 | 1.51 | 0.95 | 1.75 |
| 1985 | 0.39 | 1.22 | 0.84 | 1.65 |
| 1986 | 0.30 | 1.36 | 0.75 | 1.56 |
| 1987 | 0.46 | 0.93 | 0.67 | 1.47 |
| 1988 | 0.28 | 0.56 | 0.60 | 1.39 |
| 1989 | 0.26 | 0.99 | 0.53 | 1.31 |
| 1990 | 0.20 | 1.26 | 0.47 | 1.23 |
| 1991 | 0.20 | 1.54 | 0.42 | 1.17 |
| 1992 | 0.38 | 0.74 | 0.38 | 1.10 |
| 1993 | 0.33 | 0.89 | 0.33 | 1.04 |
| 1994 | 0.14 | 0.74 | 0.30 | 0.98 |
| 1995 | | | 0.27 | 0.93 |
| 1996 | | | 0.24 | 0.87 |
| 1997 | | | 0.21 | 0.82 |
| 1998 | 0.14 | 0.91 | 0.19 | 0.78 |
| | | | | |
| | EDB | | DBCP | |
| | $t_{1/2}$, years | 6 | $t_{1/2}$, years | 12 |
| | K[c] | 0.1155 | K[c] | 0.05775 |
| | | | | |

[a] "Average values" represent averages for the end of pumping. Averages for 1980 thru 1994 calculated in Appendix G. Average for 1998 based on results from this RI (Table 4-11).

[b] Estimated values calculated from the first order decay equation, $C = C_o * e^{(-kt)}$, where K is the first-order decay coefficient, $C_o$ is the 1980 concentration, and t is time since 1980.

[c] First-order decay coefficient ($K = .693/t_{1/2}$).



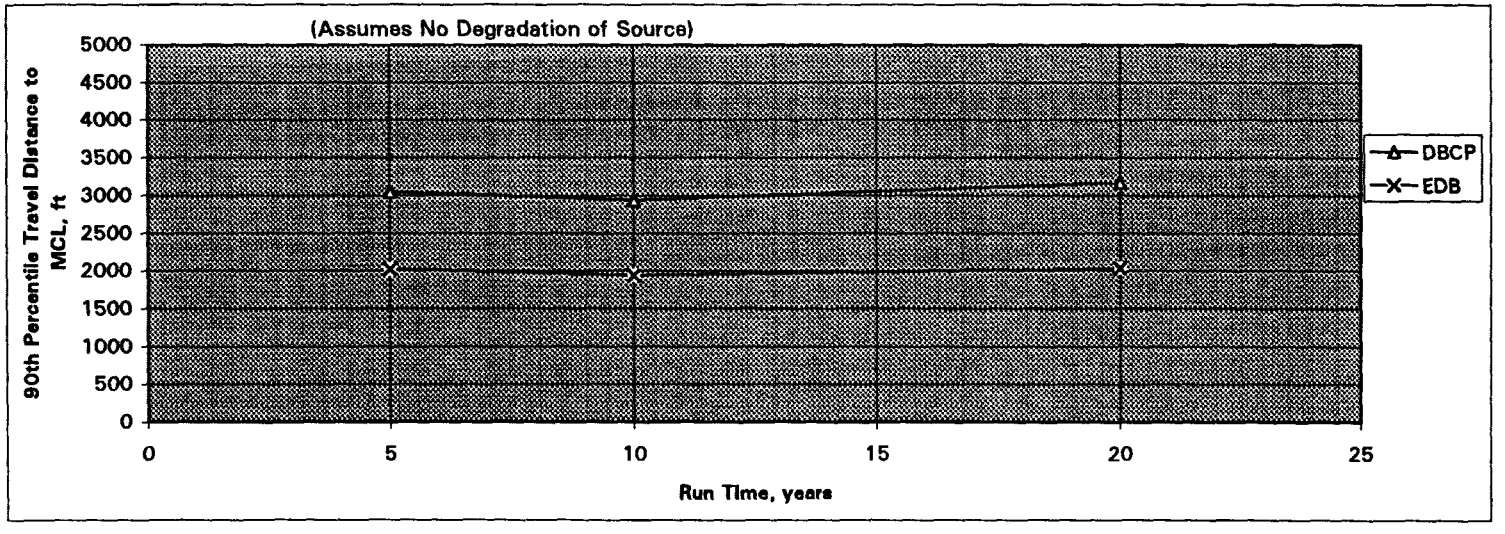
FUTURE 90TH PERCENTILE TRAVEL DISTANCES TO MCL FOR
EXISTING (1997) EDB, DBCP, DCP AND TCP (ASSUMING NO SOURCE DECAY)

| Model Run TIme, years | EDB | | DBCP | | DCP | | TCP | |
|---|---|---|---|---|---|---|---|---|
| | 90th Percentile of Travel Distances to MCL, ft | 95% UCL of Travel Distances to MCL, ft | 90th Percentile of Travel Distances to MCL, ft | 95% UCL of Travel Distances to MCL, ft | 90th Percentile of Travel Distances to MCL, ft | 95% UCL of Travel Distances to MCL, ft | 90th Percentile of Travel Distances to MCL, ft | 95% UCL of Travel Distances to MCL, ft |
| 5 | 2030 | 1385 | 3050 | 2060 | DNR | DNR | DNR | DNR |
| 10 | 1940 | 1345 | 2940 | 2060 | 20 | 19 | 87 | 83 |
| 20 | 2040 | 1385 | 3170 | 2120 | DNR | DNR | DNR | DNR |

Based on 300 realizations. See Appendix J for BIOSCREEN Model Output.
Inputs to BIOSCREEN are probabilistic estimates, shown in Figure 5-4.

UCL- Upper Confidence Limit of the Mean
DNR - Did Not Run

MCLs - EDB/DBCP = 0.04 mg/L.
- DCP = 5 mg/L
- TCP = 0.8 mg/L.

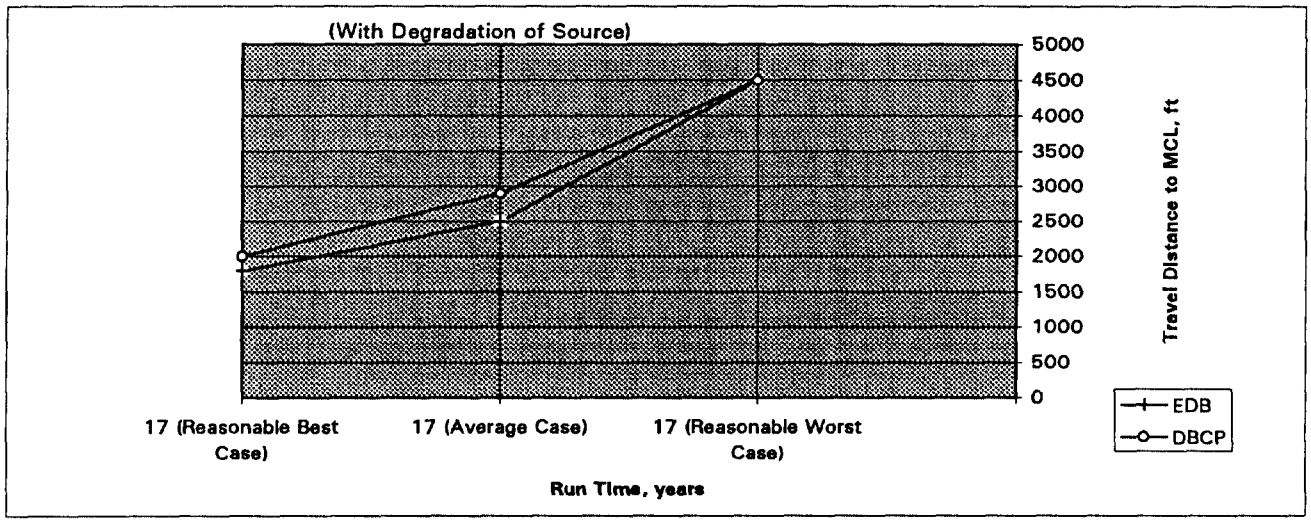


CURRENT TRAVEL DISTANCES TO MCL FOR PRIOR (1980-1997) EDB AND DBCP (WITH SOURCE DECAY)

| Model Run Time, years | EDB | DBCP |
|---|---|---|
| | | |
| 17 (Reasonable Worst Case) | 4500 | 4500 |
| 17 (Average Case) | 2500 | 2900 |
| 17 (Reasonable Best Case) | 1800 | 2000 |

(Deterministic BIOSCREEN Runs - See Appendix J for Model Output)

"Reasonable Worst Case" represents case of longitudinal dispersivity equal to 100 ft, and solute half-lives of 15 and 40 years, respectively, for EDB and DBCP.
"Average Case" represents case of longitudinal dispersivity equal to 150 ft, and solute half-lives of 10 and 20 years, respectively, for EDB and DBCP.
"Reasonable Best Case" represents case of longitudinal dispersivity equal to 200 ft, and solute half-lives of 5 and 10 years, respectively, for EDB and DBCP.
Source zone thickness is 10 ft in all cases. Groundwater velocity is 1500 ft/yr in all cases.
Source zone half-lives are 6 yrs for EDB and 12 yrs for DBCP.

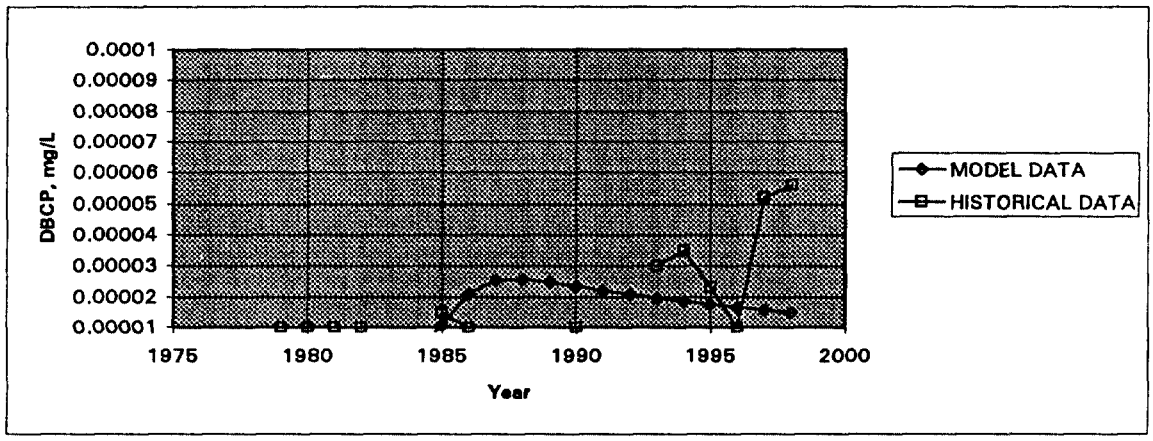


DBCP MODEL RESULTS VS HISTORICAL DBCP AT THE HCC WELL

| Year | Model Year | Model Estimate[b], mg/L | Historical Data[a], mg/L |
|---|---|---|---|
| 1979 | | | 1.00E-05 |
| 1980 | 0 | | 1.00E-05 |
| 1981 | 1 | 0 | 1.00E-05 |
| 1982 | 2 | 1.57E-12 | 1.00E-05 |
| 1983 | 3 | 3.45E-08 | |
| 1984 | 4 | 1.93E-06 | |
| 1985 | 5 | 1.09E-05 | 1.50E-05 |
| 1986 | 6 | 2.11E-05 | 1.00E-05 |
| 1987 | 7 | 2.54E-05 | |
| 1988 | 8 | 2.57E-05 | |
| 1989 | 9 | 2.47E-05 | |
| 1990 | 10 | 2.34E-05 | 1.00E-05 |
| 1991 | 11 | 2.21E-05 | |
| 1992 | 12 | 2.09E-05 | |
| 1993 | 13 | 1.98E-05 | 3.00E-05 |
| 1994 | 14 | 1.87E-05 | 3.50E-05 |
| 1995 | 15 | 1.77E-05 | 2.33E-05 |
| 1996 | 16 | 1.67E-05 | 1.00E-05 |
| 1997 | 17 | 1.58E-05 | 5.20E-05 |
| 1998 | 18 | 1.49E-05 | 5.60E-05 |

[a] - Historical data has been modified to produce a single average value for each year.
Data thru 1995 are from Figure 2-5 of the Work Plan (ICF 1997).
1996/97 data are from the HDOH. 1998 data are from this RI (Table 4-12).
All historical data up until 1993 are non-detects. Value shown is 1/2 the detection limit.

[b] - Model results shown are BIOSCREEN output at a distance of 8000 ft from the source assuming "average case" conditions, as discussed in Section 5.3.4.3.

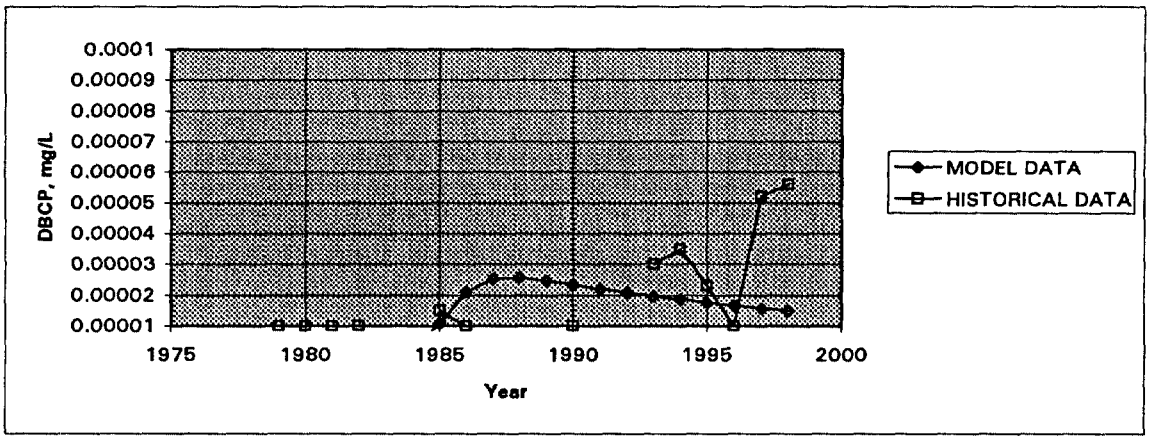


DBCP MODEL RESULTS VS HISTORICAL DBCP AT THE HCC WELL

| Year | Model Year | Model Estimate[b], mg/L | Historical Data[a], mg/L |
|---|---|---|---|
| 1979 | | | 1.00E-05 |
| 1980 | 0 | | 1.00E-05 |
| 1981 | 1 | 0 | 1.00E-05 |
| 1982 | 2 | 1.57E-12 | 1.00E-05 |
| 1983 | 3 | 3.45E-08 | |
| 1984 | 4 | 1.93E-06 | |
| 1985 | 5 | 1.09E-05 | 1.50E-05 |
| 1986 | 6 | 2.11E-05 | 1.00E-05 |
| 1987 | 7 | 2.54E-05 | |
| 1988 | 8 | 2.57E-05 | |
| 1989 | 9 | 2.47E-05 | |
| 1990 | 10 | 2.34E-05 | 1.00E-05 |
| 1991 | 11 | 2.21E-05 | |
| 1992 | 12 | 2.09E-05 | |
| 1993 | 13 | 1.98E-05 | 3.00E-05 |
| 1994 | 14 | 1.87E-05 | 3.50E-05 |
| 1995 | 15 | 1.77E-05 | 2.33E-05 |
| 1996 | 16 | 1.67E-05 | 1.00E-05 |
| 1997 | 17 | 1.58E-05 | 5.20E-05 |
| 1998 | 18 | 1.49E-05 | 5.60E-05 |

[a] - Historical data has been modified to produce a single average value for each year.
Data thru 1995 are from Figure 2-5 of the Work Plan (ICF 1997).
1996/97 data are from the HDOH. 1998 data are from this RI (Table 4-12).
All historical data up until 1993 are non-detects. Value shown is 1/2 the detection limit.

[b] - Model results shown are BIOSCREEN output at a distance of 8000 ft from the source assuming "average case" conditions, as discussed in Section 5.3.4.3.



# FIGURES

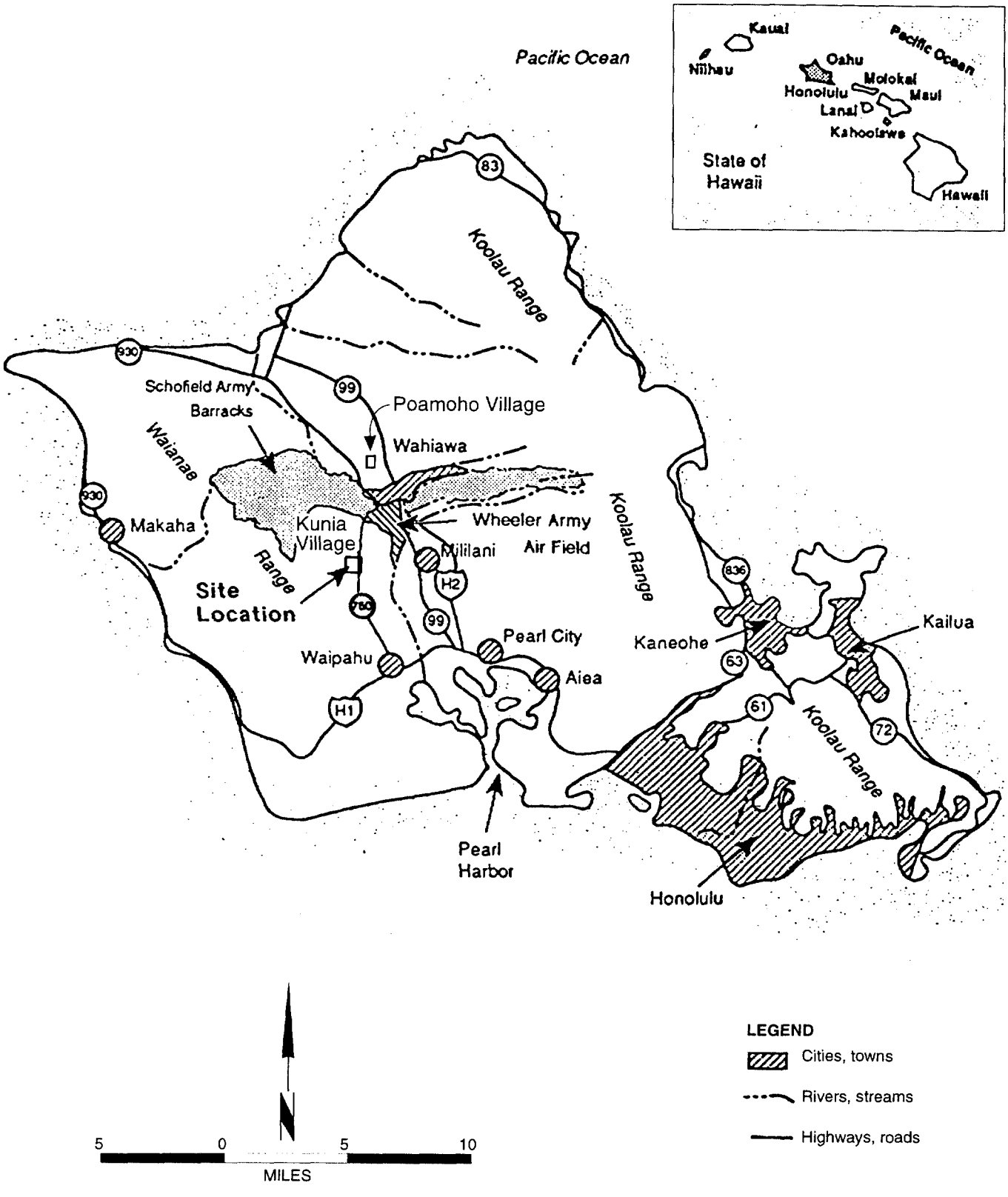



FIGURE **1-1**

**DEL MONTE CORPORATION (OAHU PLANTATION)**

**SITE LOCATION MAP**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76106 DATE 12/5/97 DRAWN BY EA

**Golder Associates**

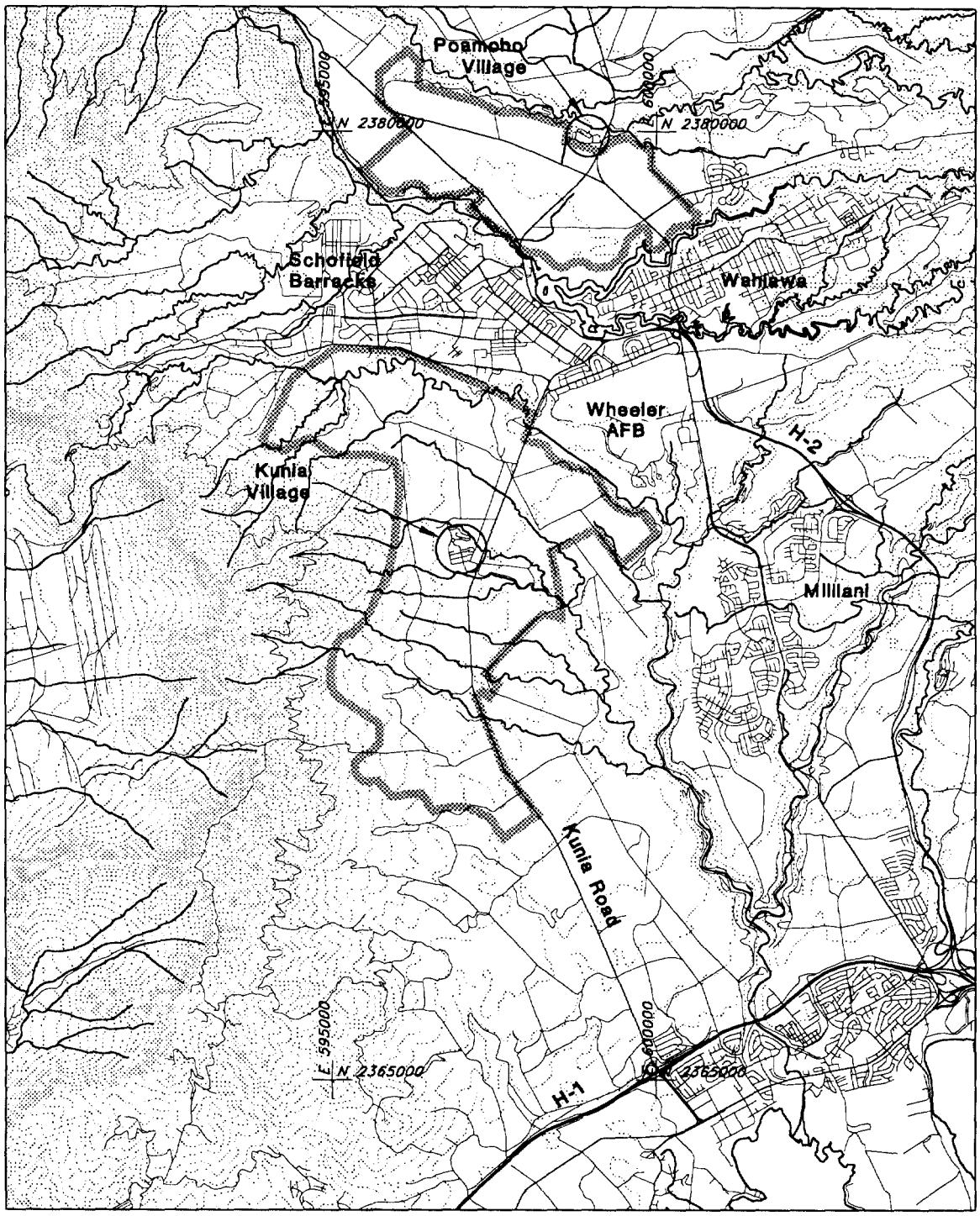
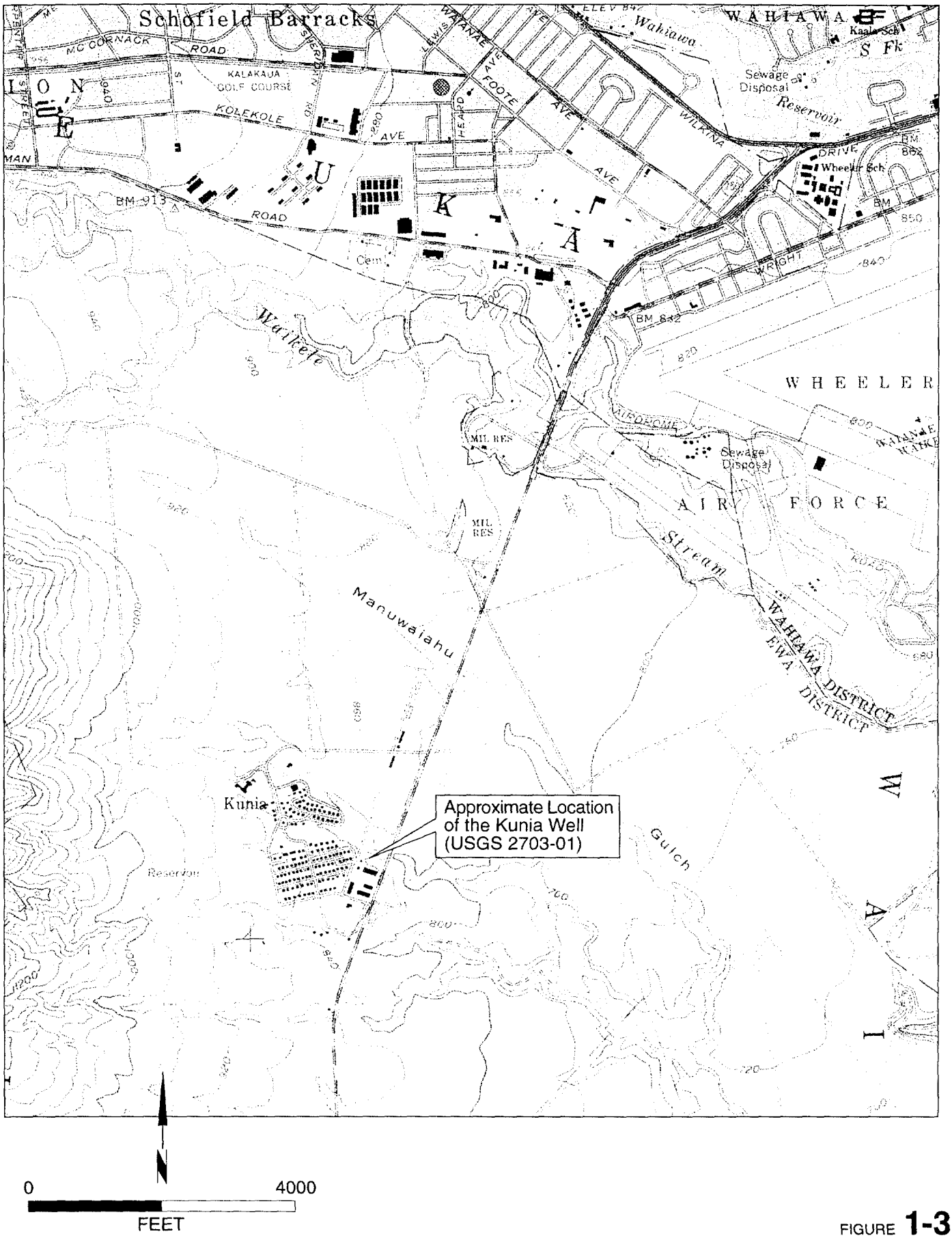



FIGURE **1-2**
**SITE PLAN**
DEL MONTE/OAHU/HI

CAD_4 | K:\CAD\SDSKPROJ\9631532\4000\CLIENT\69867.DWG | 3-17-98 15:57 | xrf: CONTOUR2

**Golder Associates**




Source: USGS 7.5 minute quad "Schofield Barracks".

FIGURE **1-3**

**KUNIA VILLAGE VICINITY**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76107 DATE 2/12/98 DRAWN BY EA

**Golder Associates**

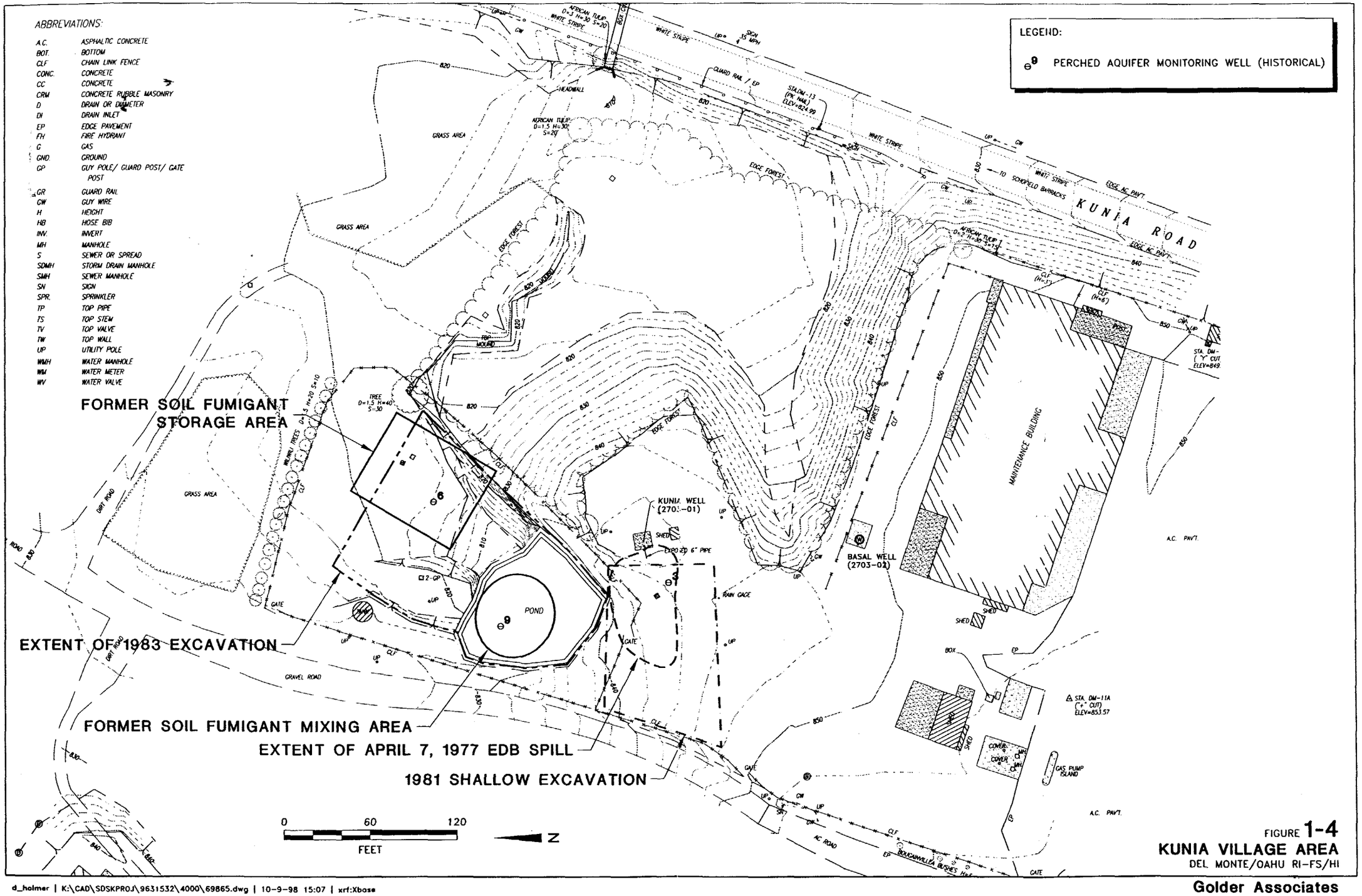



FIGURE 1-4
KUNIA VILLAGE AREA
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69865.dwg | 10-9-98 15:07 | xrf:Xbase

Golder Associates

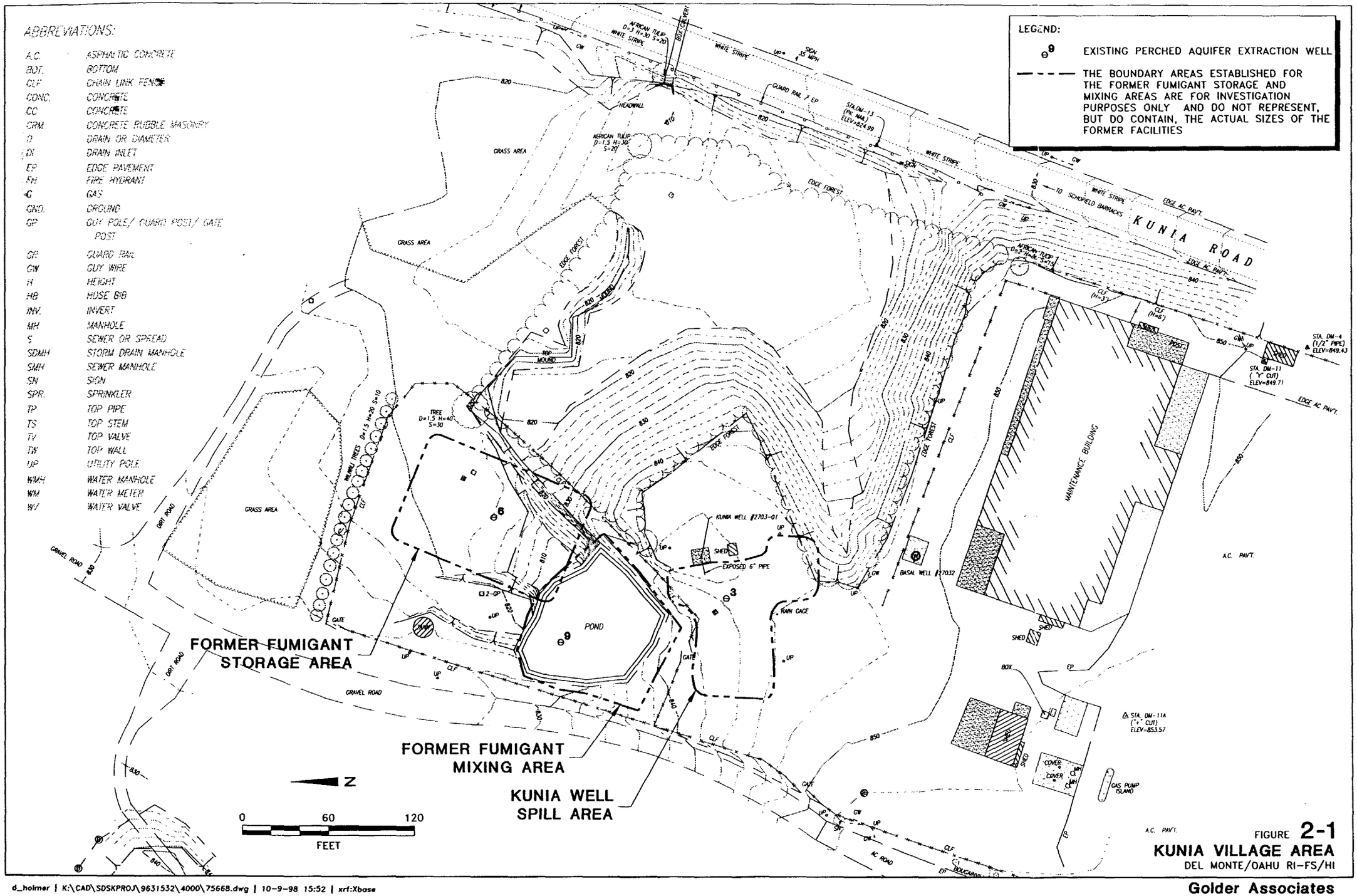



FIGURE 2-1
**KUNIA VILLAGE AREA**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\75668.dwg | 10-9-98 15:52 | xrf:Xbase

**Golder Associates**

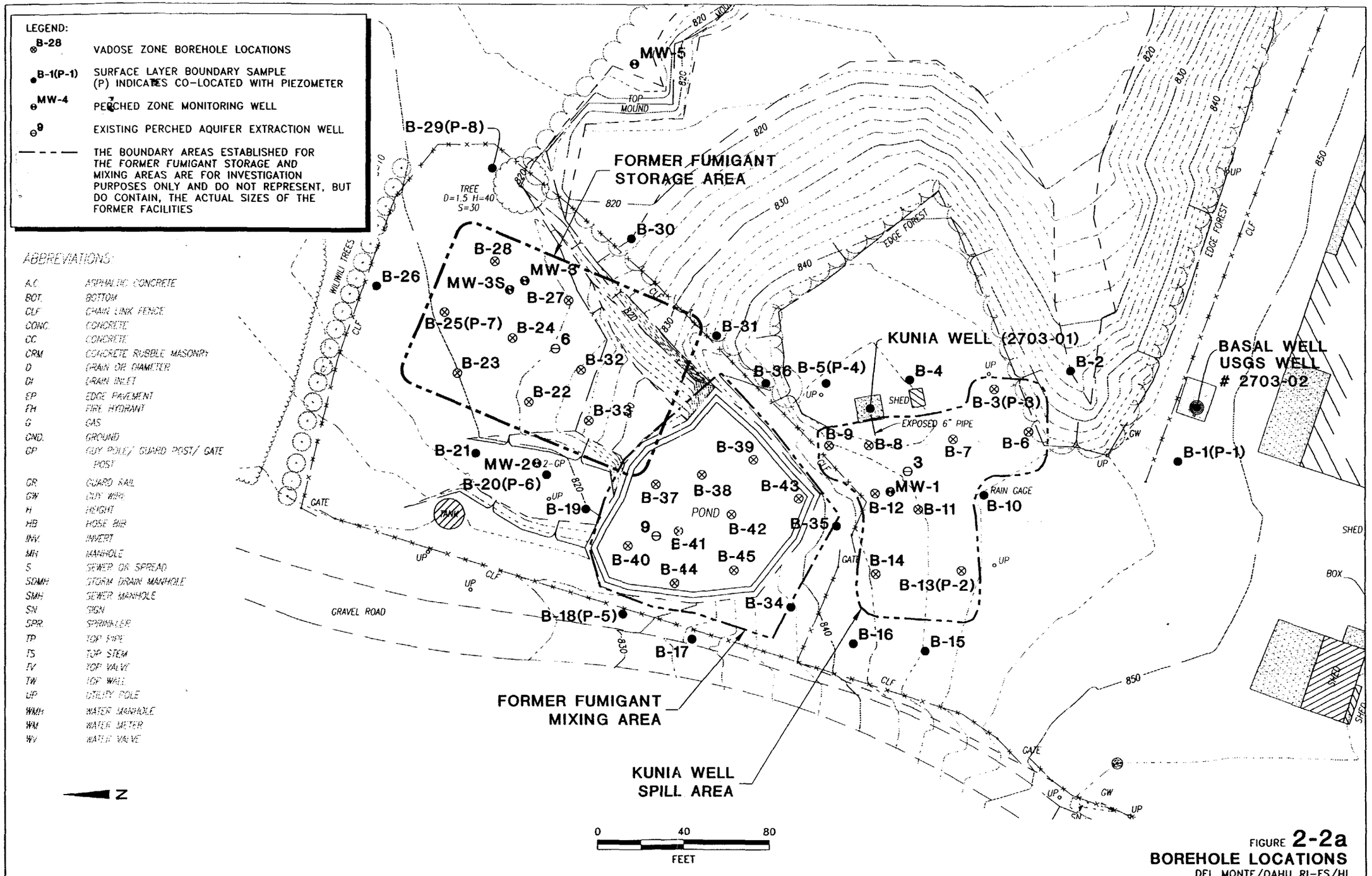



FIGURE 2-2a
BOREHOLE LOCATIONS
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\79679.dwg | 10-9-98 14:21 | xrf:Xbase

Golder Associates

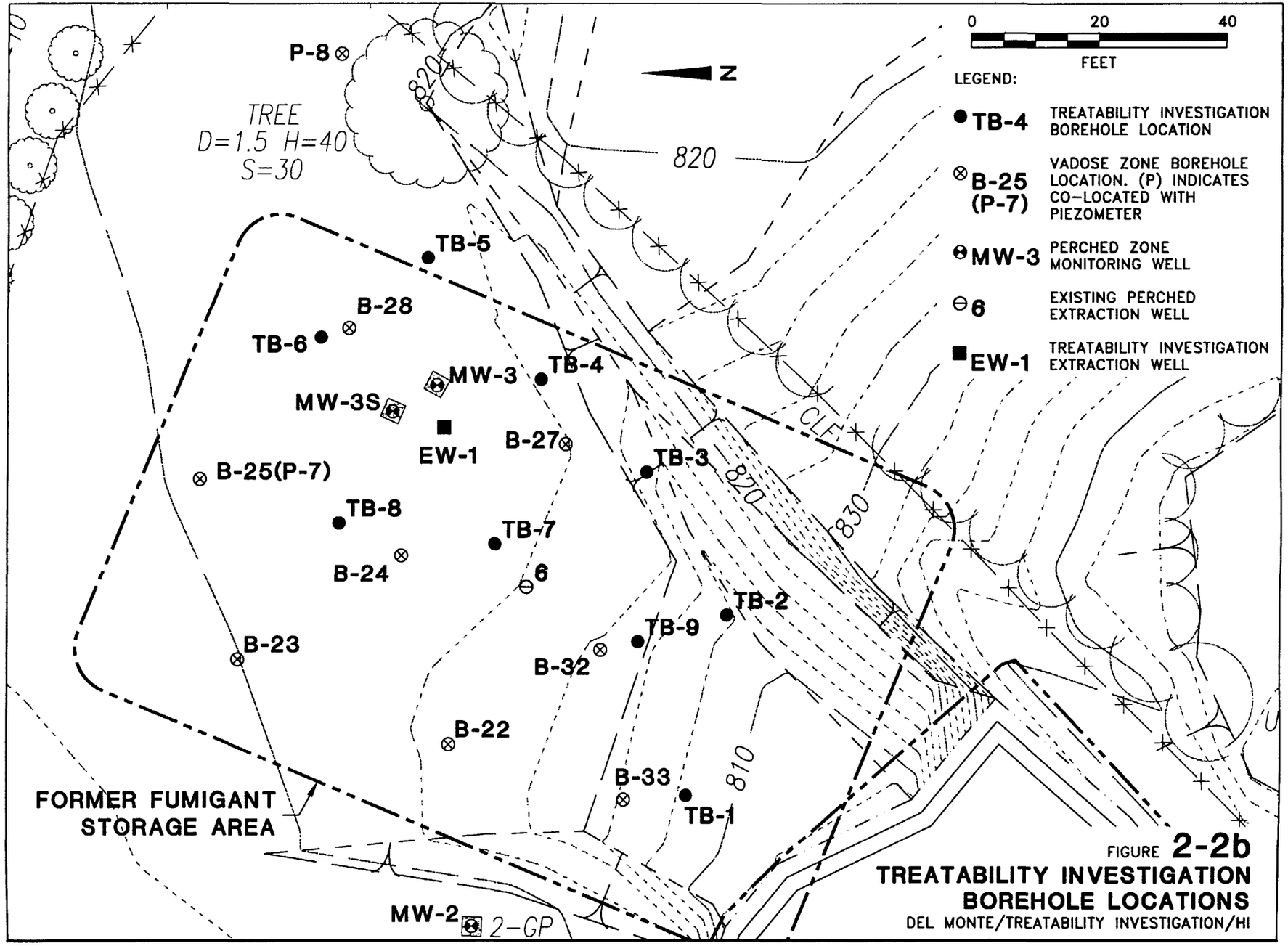



FIGURE 2-2b
TREATABILITY INVESTIGATION BOREHOLE LOCATIONS
DEL MONTE/TREATABILITY INVESTIGATION/HI

d_holmer|K:\CAD\SDSKPROJ\9631532\4000\78227.dwg|12-2-98 14:23|x:Xbase|i:-

Golder Associates

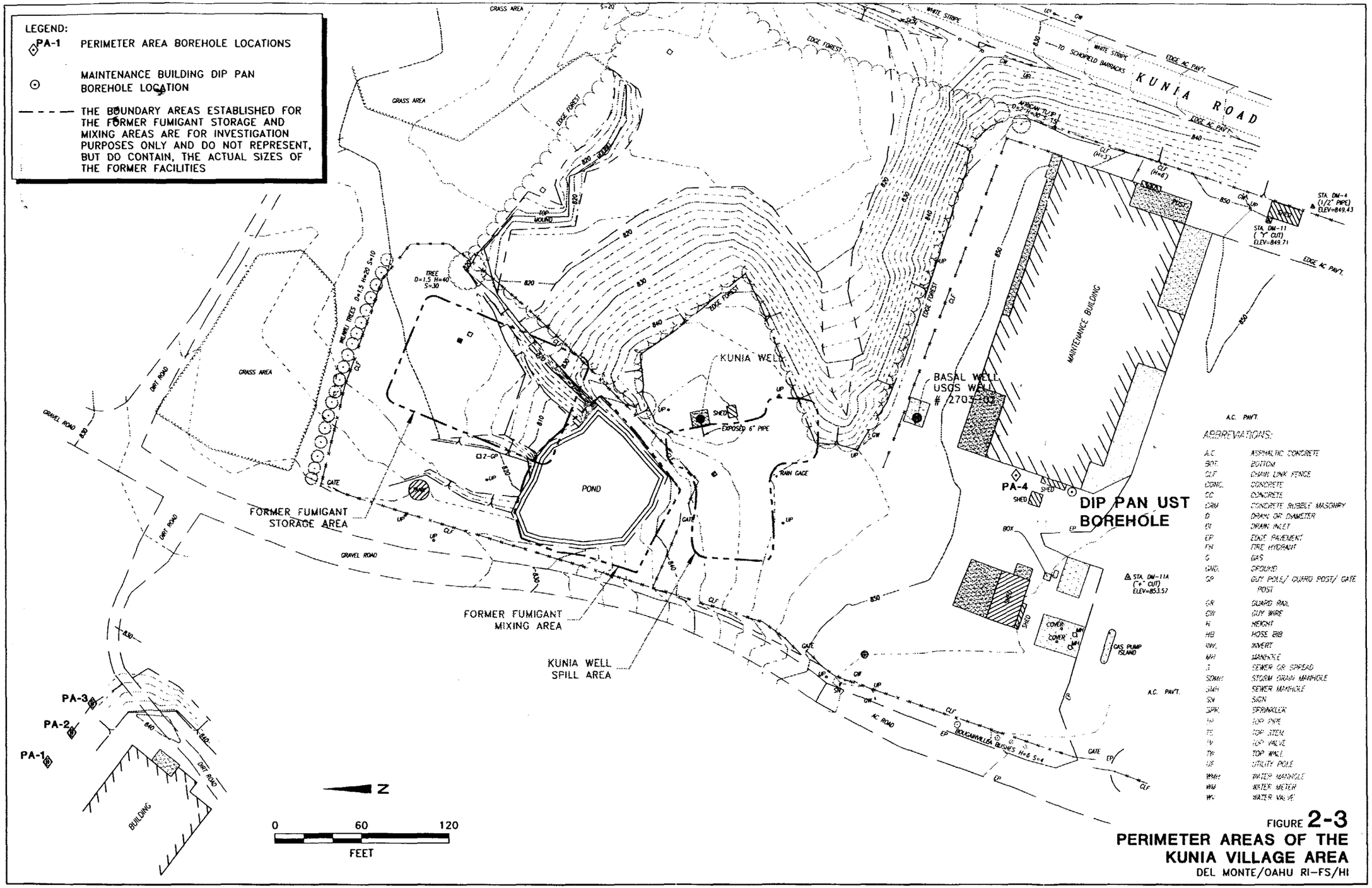



FIGURE 2-3
**PERIMETER AREAS OF THE KUNIA VILLAGE AREA**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\963153Z\4000\75670.dwg | 10-9-98 14:07 | xrf:Xbase

**Golder Associates**

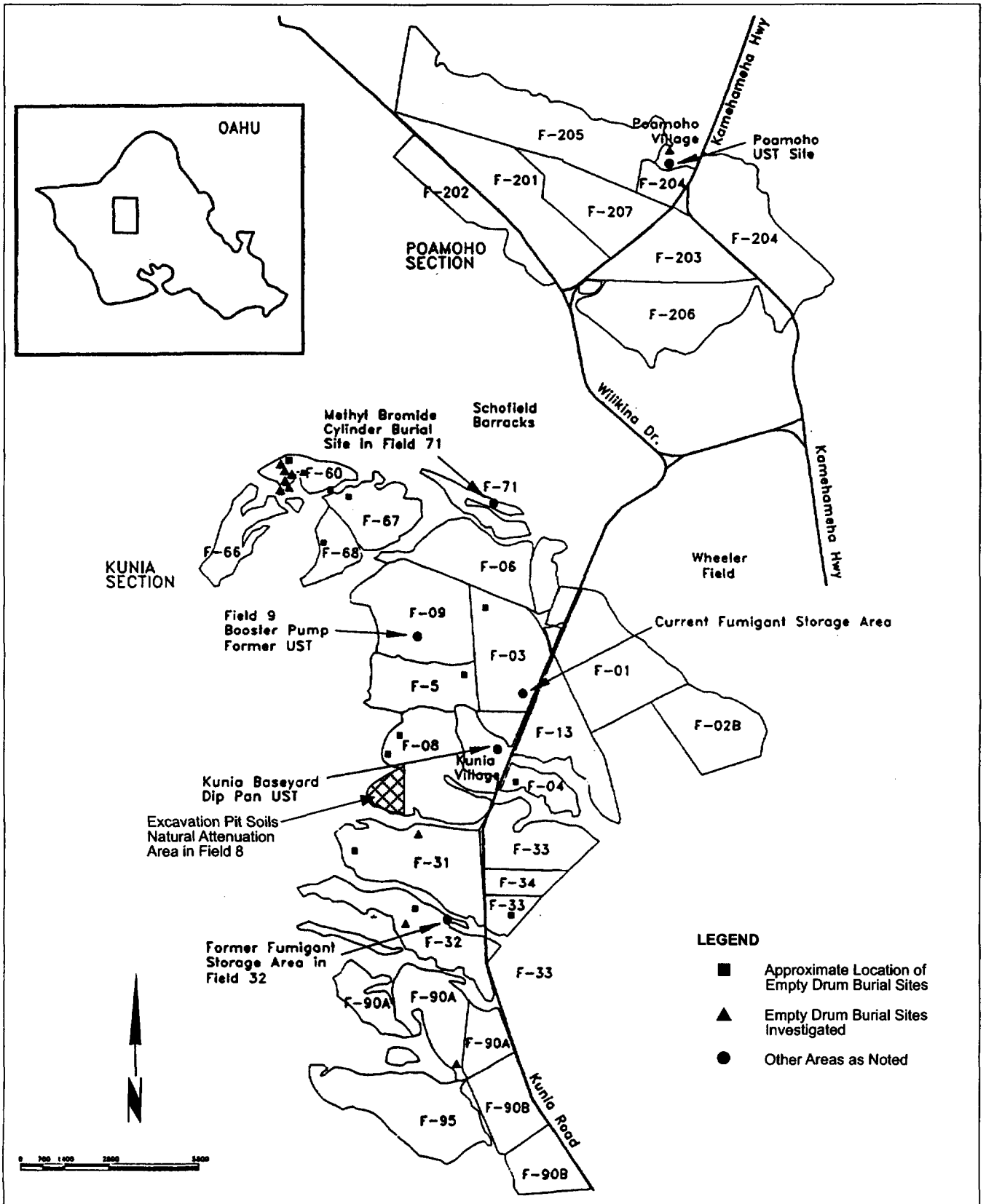



FIGURE **2-4**

**LOCATIONS OF OTHER POTENTIAL SOURCE AREAS**
**DEL MONTE CORPORATION OAHU PLANTATION**

DEL MONTE/OAHU RI-FS/HI

DRAWING NO. 96315328000fg03.fh9 DATE 02/21/03 DRAWN BY EFS

**Golder Associates**

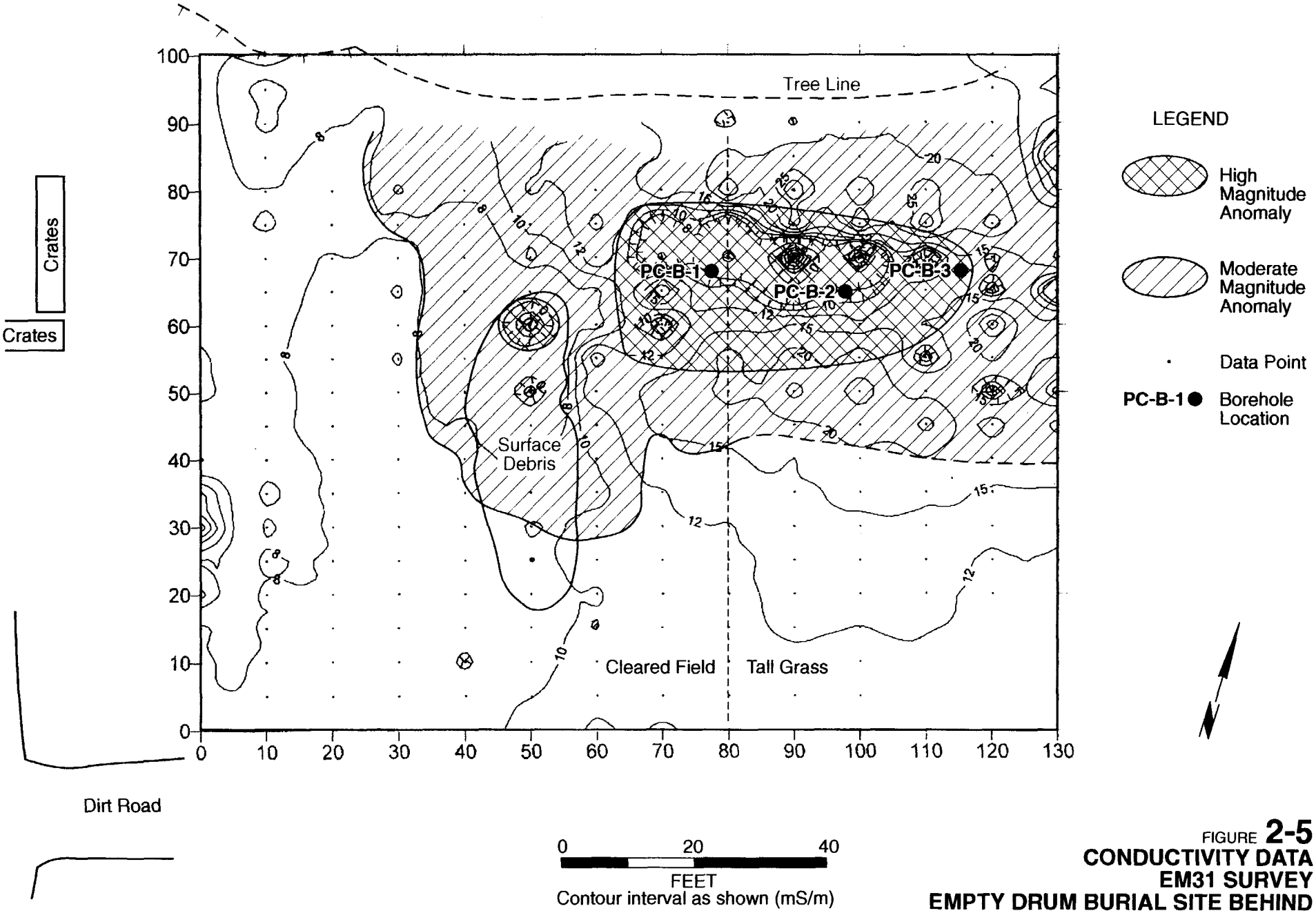
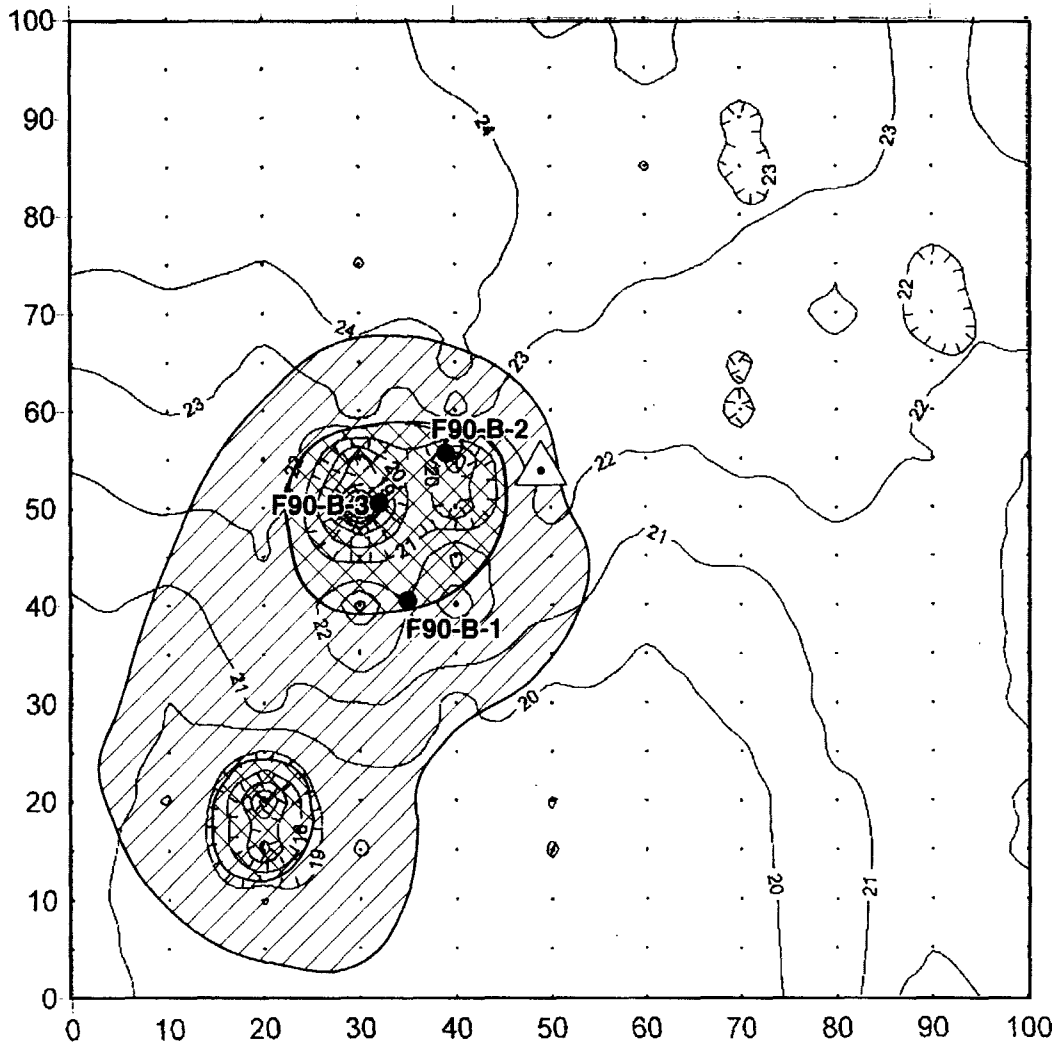



FIGURE **2-5**
**CONDUCTIVITY DATA**
**EM31 SURVEY**
**EMPTY DRUM BURIAL SITE BEHIND**
**THE POAMOHO CRATE YARD**
DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 72209 DATE 3/11/98 DRAWN BY TK

**Golder Associates**




LEGEND

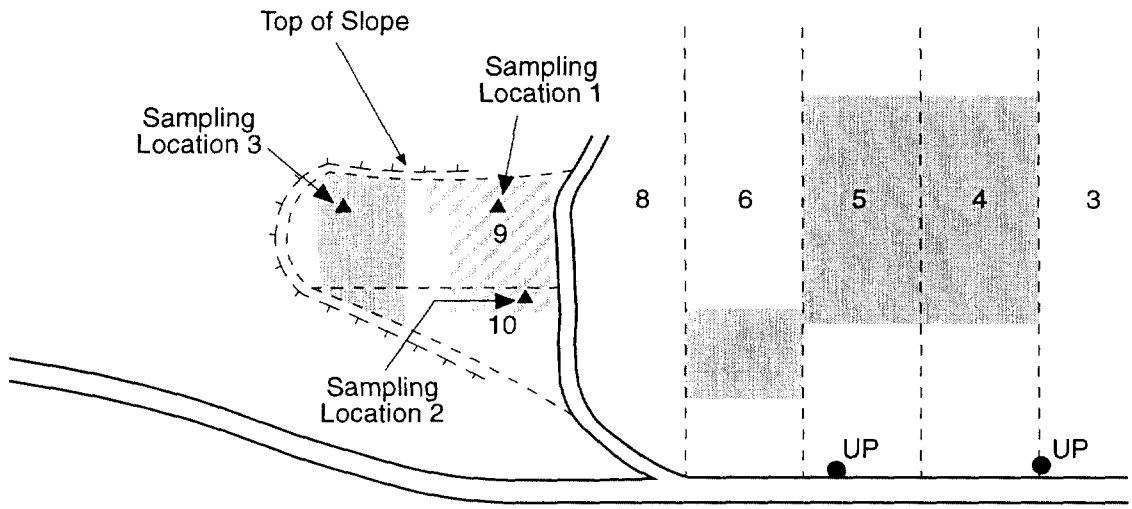
- Data Point
- Del Monte Control Point
- High Magnitude Anomaly
- Low Magnitude Anomaly
- F90-B-1● Borehole Locations

0 20 40
FEET
Contour Interval = 1 mS/m

FIGURE **2-6**
**CONDUCTIVITY DATA**
**EM31 SURVEY**
**EMPTY DRUM BURIAL SITE IN FIELD 90A**
DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 72220 DATE 3/11/98 DRAWN BY TK

**Golder Associates**




**LEGEND**

5 Block Boundary with Number

Dirt Road

1998 Geophysical Survey

1997 Geophysical Survey

UP Utility Pole

Recorded Location of Empty Drum Burial Site

0 200 400

SCALE IN FEET (APPROXIMATE)

FIGURE **2-7a**

**SITE MAP**

**FIELD 60 GEOPHYSICAL SURVEY**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 80893 DATE 10/9/98 DRAWN BY EA

**Golder Associates**

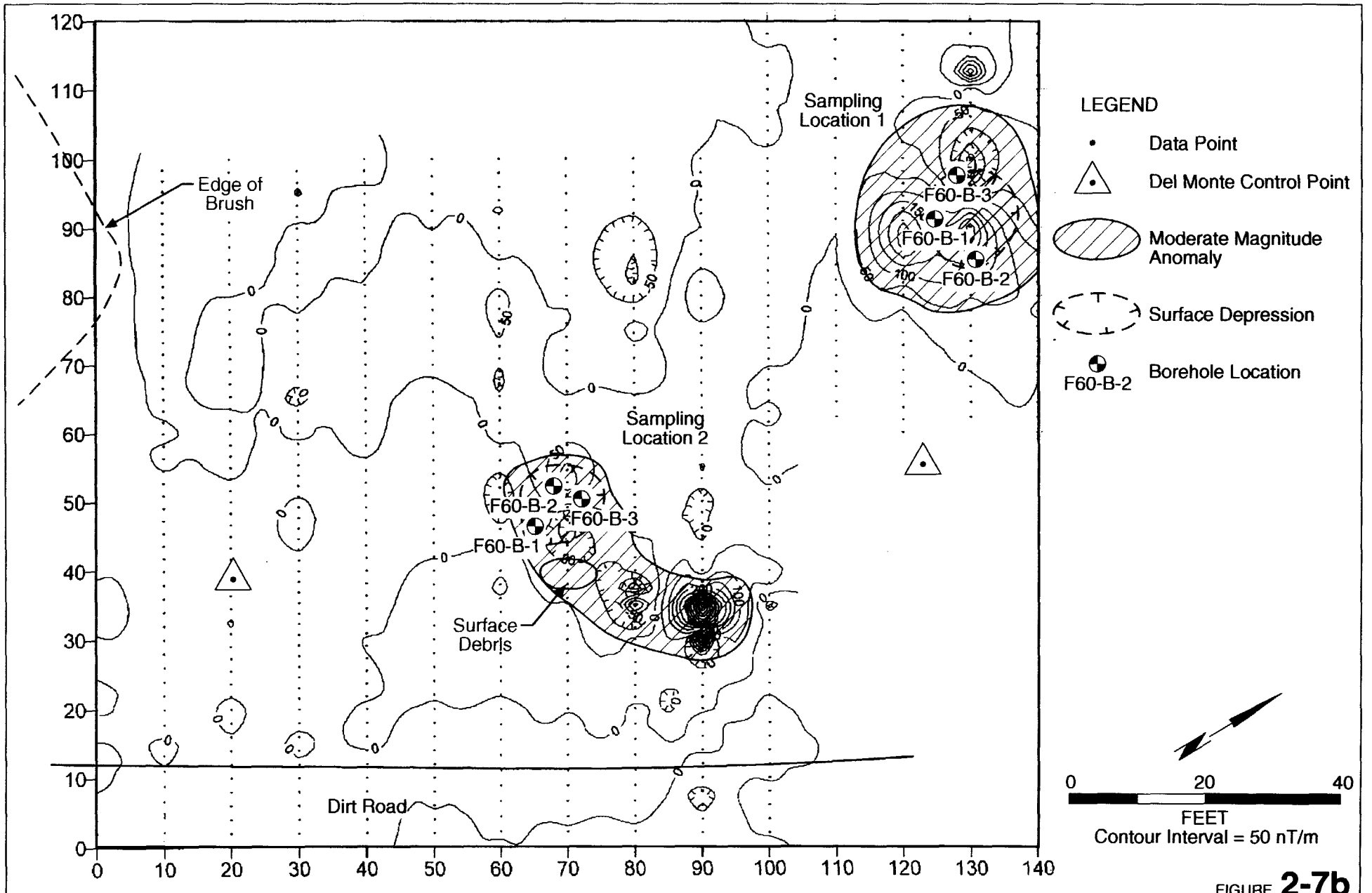


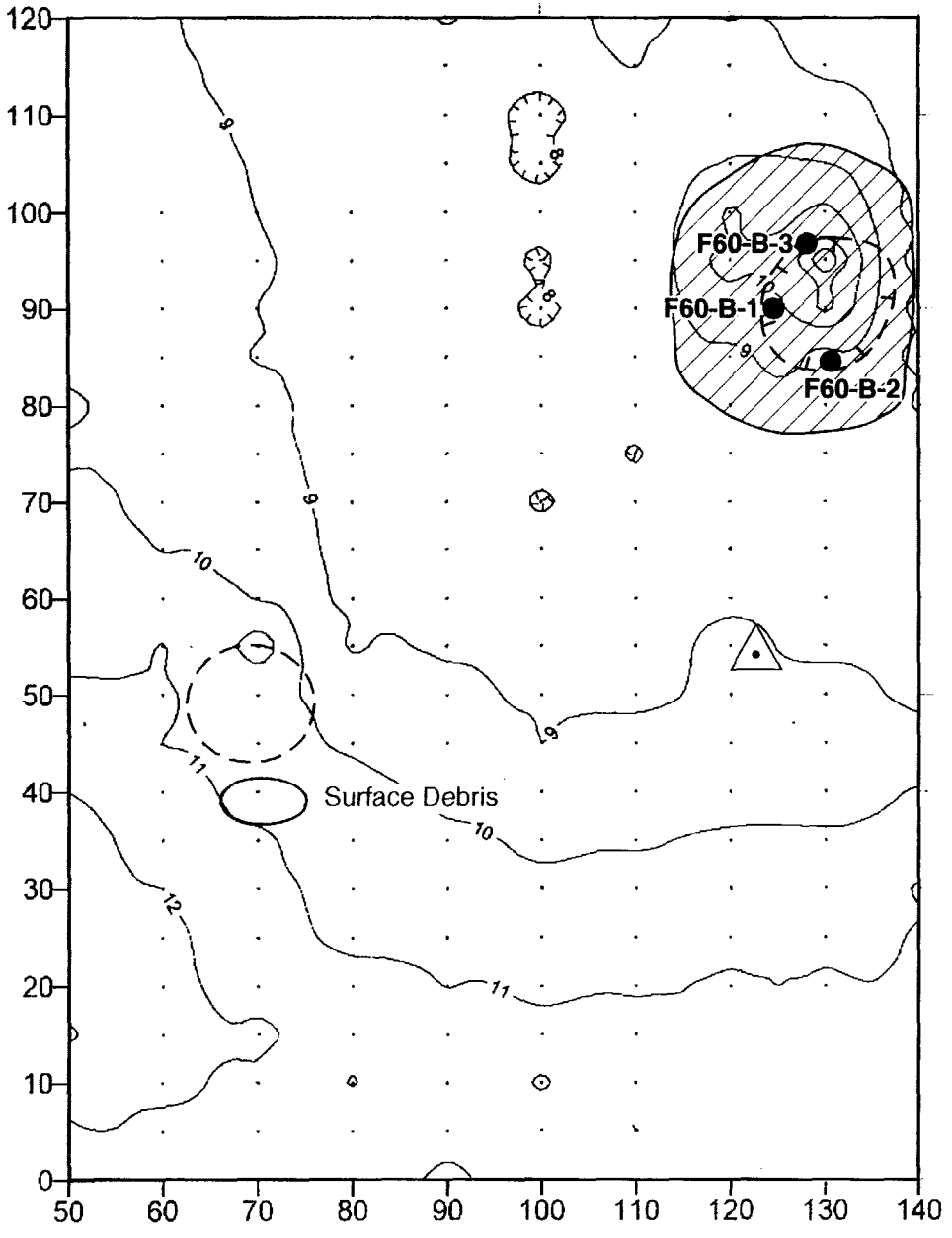

FIGURE **2-7b**

**VERTICAL GRADIENT DATA MAGNETOMETER SURVEY FIELD 60**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 80894 DATE 10/9/98 DRAWN BY EA

**Golder Associates**




LEGEND

- Data Point
- Del Monte Control Point
- Moderate Magnitude Anomaly
- Surface Depression
- F60-B-1 Borehole Location

0 20 40

FEET

Contour Interval = 1 mS/m

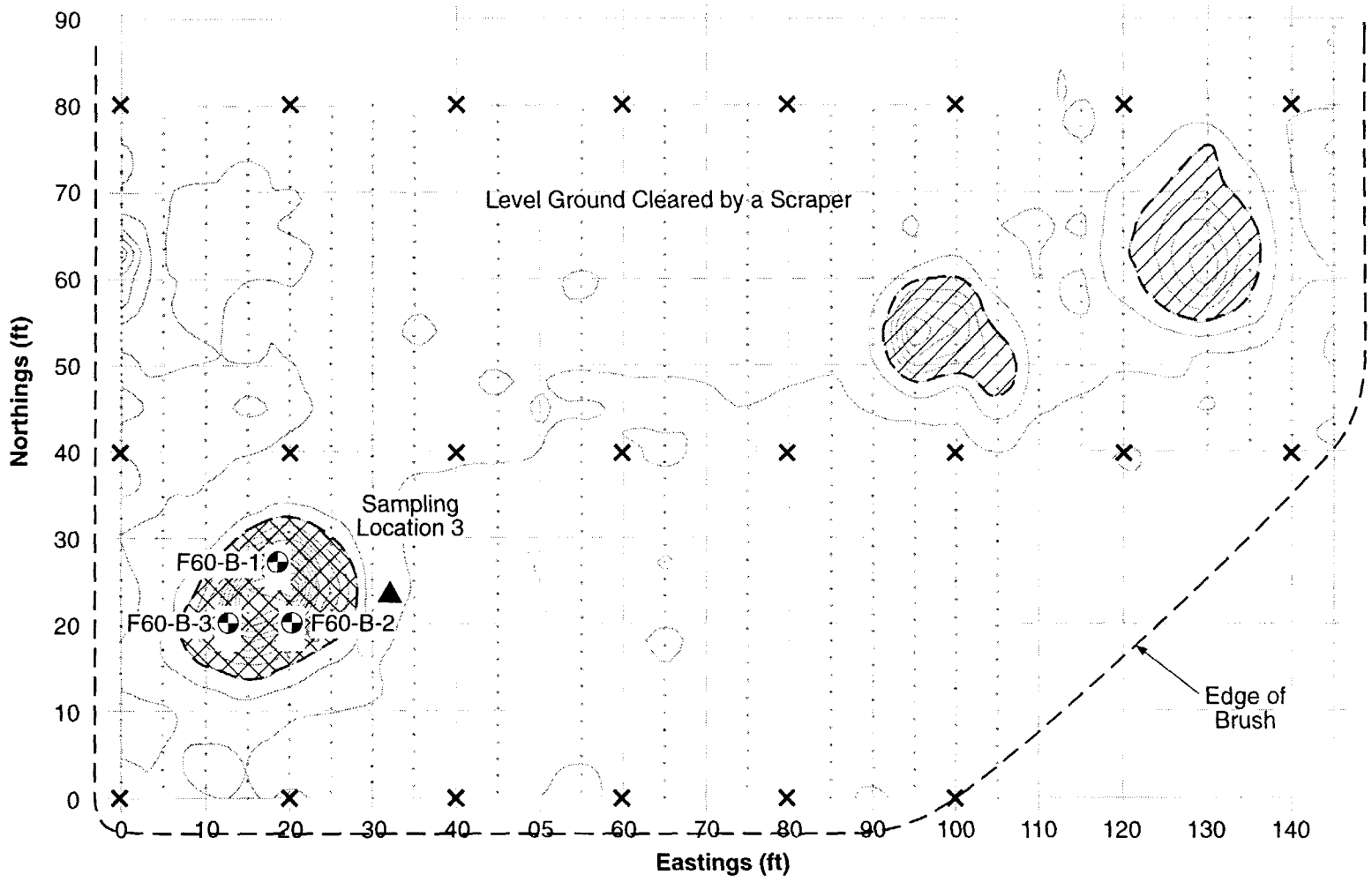
FIGURE **2-7c**

**CONDUCTIVITY DATA**
**EM31 SURVEY**
**FIELD 60**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 80895 DATE 10/9/98 DRAWN BY EA

**Golder Associates**




**LEGEND**

- ▲ Recorded Location of Empty Drum Burial Site
- × Control Grid Stake
- Moderate Magnitude Anomaly
- Low Magnitude Anomaly
- Contour Interval is 5 mV
- F60-B-1 ⊕ Borehole Location

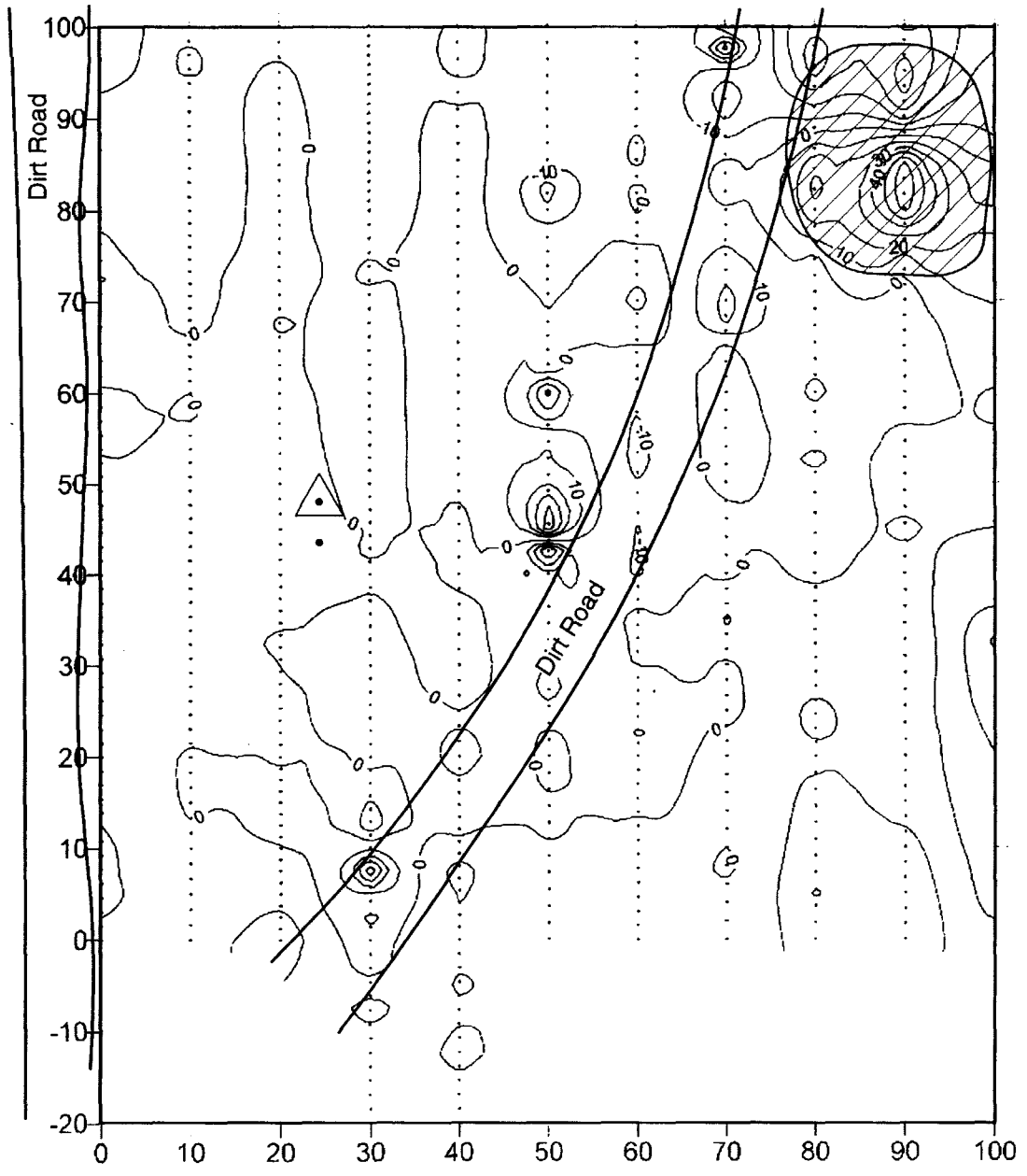
N

0 20
FEET

FIGURE **2-7d**
**EM61 DATA**
**SOUTH END OF BLOCKS 9 & 10**
**FIELD 60**
DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 9631532.4000 DRAWING NO. 80896 DATE 10/13/98 DRAWN BY EA

**Golder Associates**




LEGEND

- Data Point
- Del Monte Control Point
- Moderate Magnitude Anomaly

N

0 20 40

FEET

Contour Interval = 10 nT/m

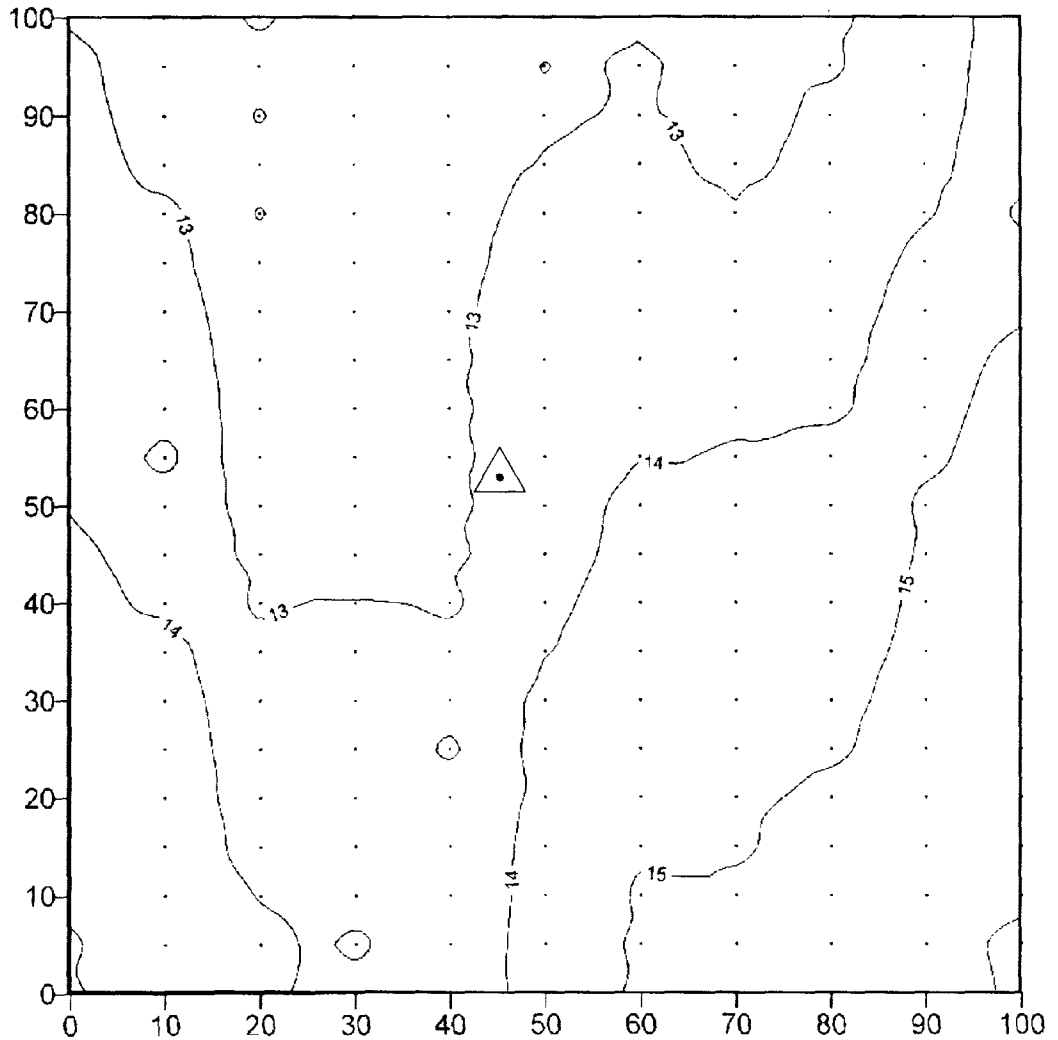
FIGURE **2-8**

**VERTICAL GRADIENT DATA**
**MAGNETOMETER SURVEY**
**EMPTY DRUM BURIAL SITE IN FIELD 31**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 72211 DATE 3/11/98 DRAWN BY TK

**Golder Associates**




LEGEND

• Data Point

Del Monte Control Point

0 20 40

FEET

Contour Interval = 1 mS/m

FIGURE **2-9**

**CONDUCTIVITY DATA**

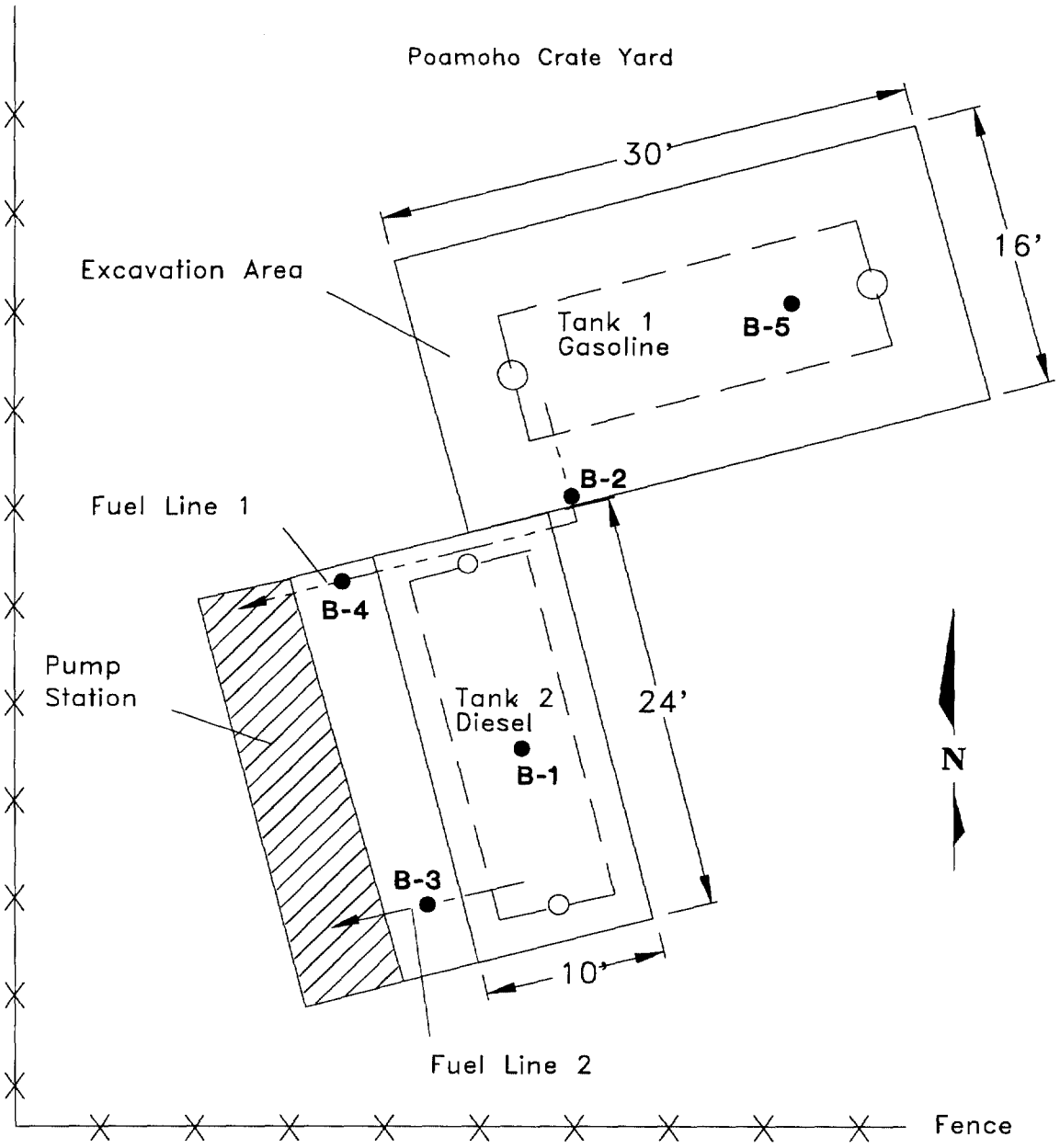
**EM31 SURVEY**

**EMPTY DRUM BURIAL SITE IN FIELD 32**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 72214 DATE 3/11/98 DRAWN BY TK

**Golder Associates**




LEGEND

- ○ Previous Soil Boring
- ● B-1 Soil Boring Location
- ▭ Estimated Tank Location

Reference: ICF Technology 1996

Tank 1
Contents: Gasoline
Capacity: 6,000 Approx.
Size: 20'(L) X 7'(DIA)
Closure: 1987

Tank 2
Contents: Diesel Fuel No. 2
Capacity: 6,000 Approx.
Size: 20'(L) X 7'(DIA)
Closure: 1987

0 10 20
FEET

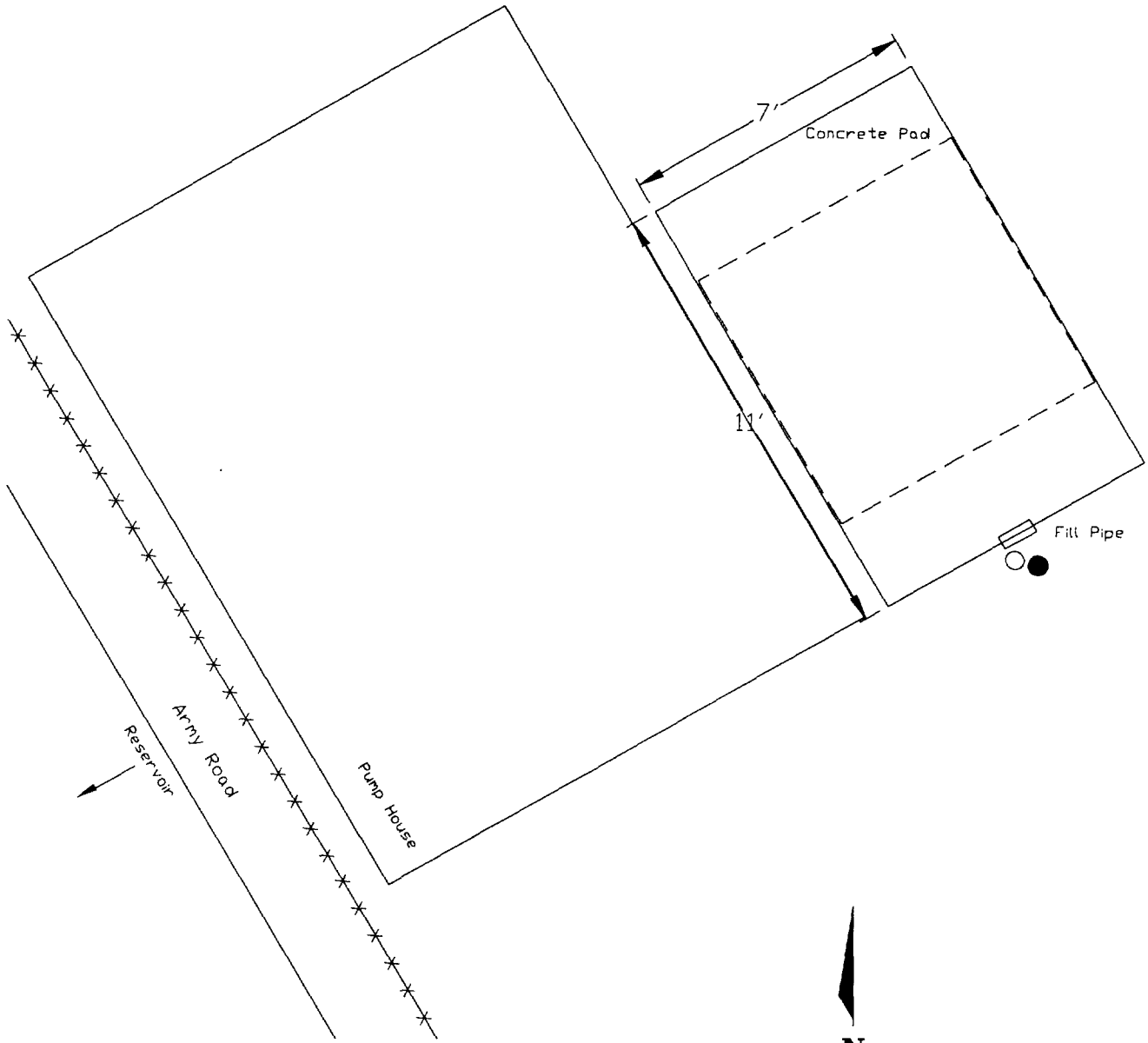
FIGURE **2-10**

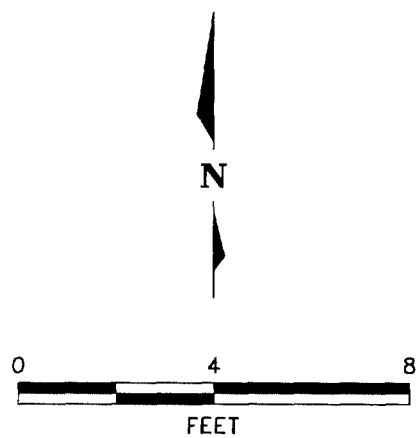
**SOIL BORING LOCATIONS SCHEMATIC OF POAMOHO CRATE YARD - FORMER UST LOCATIONS DEL MONTE CORP. (OAHU PLANTATION)**

DEL MONTE/OAHU RI-FS/HI

D_HOLMER | K:\CAD\SDSKPROJ\9631532\4000\69913.DWG | 1-12-98 15:55 | xrf: NONE

**Golder Associates**




LEGEND

- ○ Previous Boring
- ● Soil Boring Location
- ▭ Proposed Soil Boring

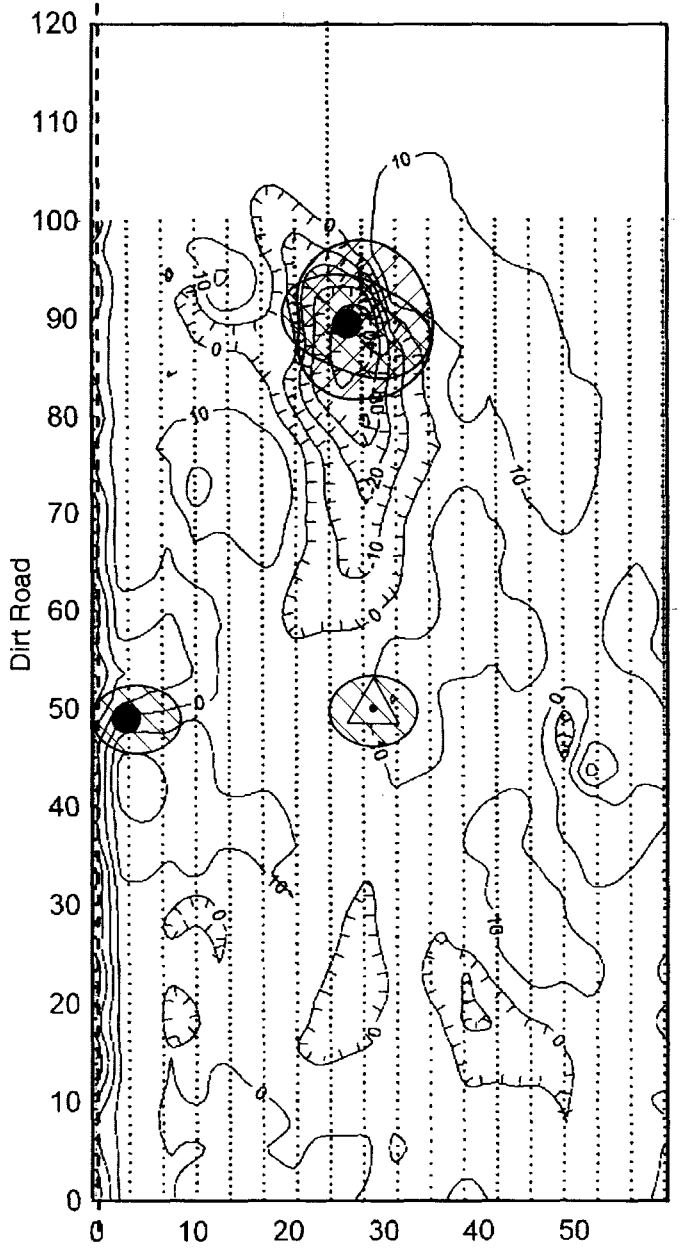
Reference: ICF Technology 1996

Former UST
Location: Field 9
Contents: Diesel Fuel No. 2
Capacity: Approx. 2,000 GALS.
Size: 7' (L) X 7' (DIA)
Closure: 1986

FIGURE **2-11**

**SOIL BORING LOCATIONS SCHEMATIC OF FIELD 9 BOOSTER STORAGE TANK - FORMER UST SYSTEM DEL MONTE CORP. (OAHU PLANTATION)**

DEL MONTE/OAHU RI-FS/HI




LEGEND

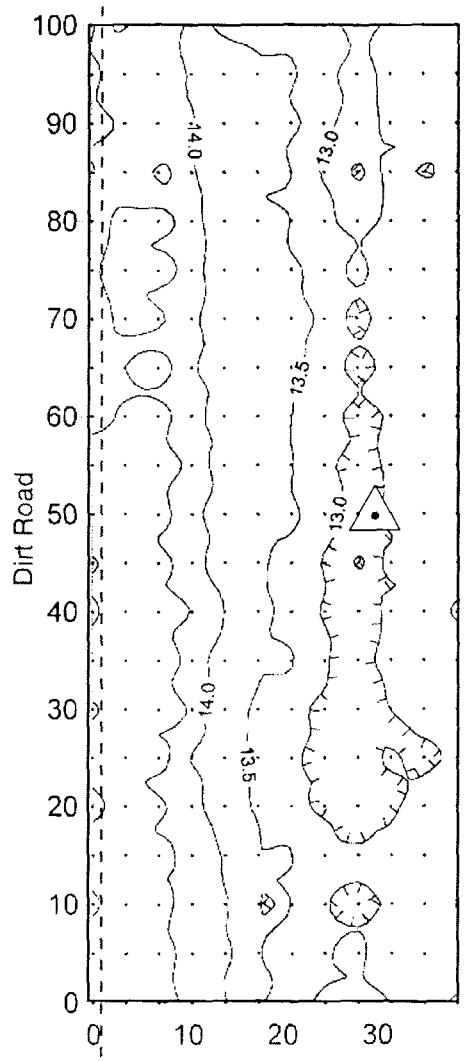
- Data Point
- Del Monte Control Point
- Possible Target Locations
- Moderate Magnitude Anomaly
- Backhoe Exploratory Excavation Areas

0 20 40
FEET
Contour Interval = 10 nT/m

FIGURE **2-12a**
**VERTICAL GRADIENT DATA MAGNETOMETER SURVEY METHYL BROMIDE CYLINDER BURIAL AREA IN FIELD 71**
DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 72217 DATE 3/10/98 DRAWN BY TK

**Golder Associates**




LEGEND

- Data Point
- Del Monte Control Point

0 20 40

FEET

Contour Interval = 0.5 mS/m

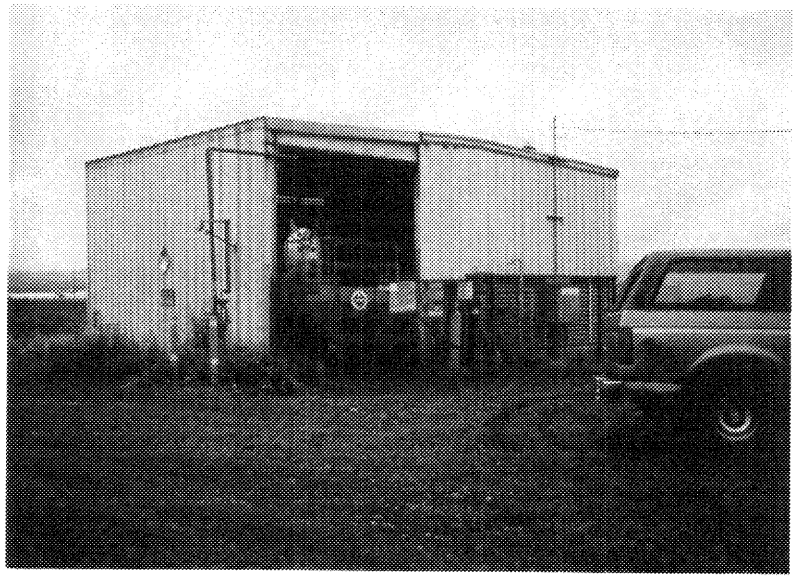
FIGURE **2-12b**

**CONDUCTIVITY DATA**
**EM31 SURVEY**
**METHYL BROMIDE CYLINDER**
**BURIAL AREA IN FIELD 71**

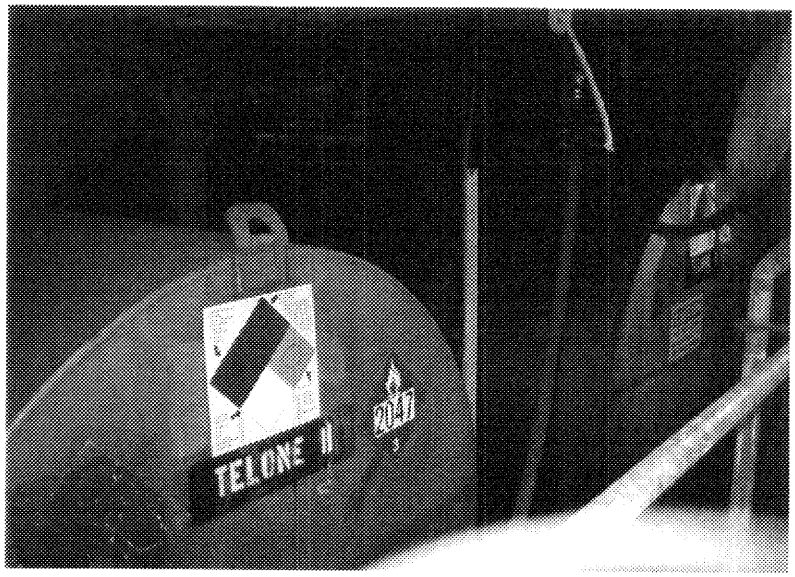
DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76776 DATE 4/23/98 DRAWN BY TK

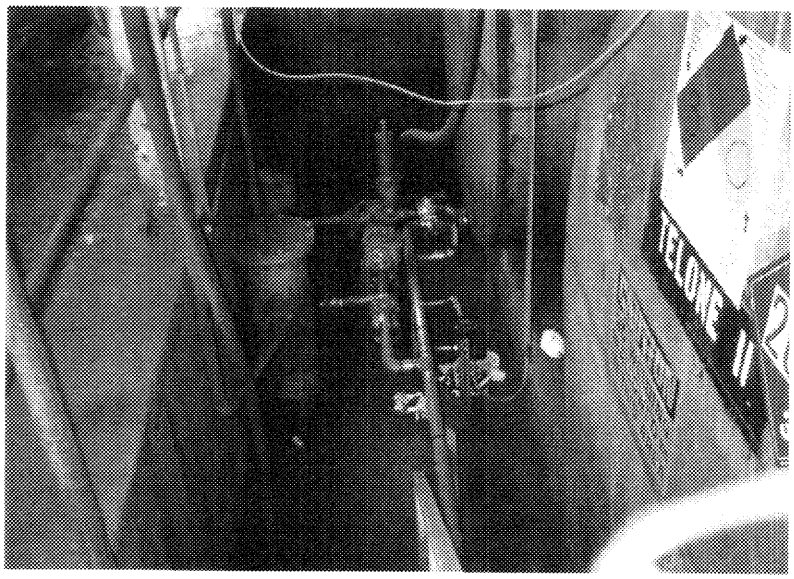
**Golder Associates**



A. Current soil fumigant storage facility.




B. 5,000-gallon soil fumigant storage tanks.




C. Current soil fumigant storage area fireproof valves and filter.

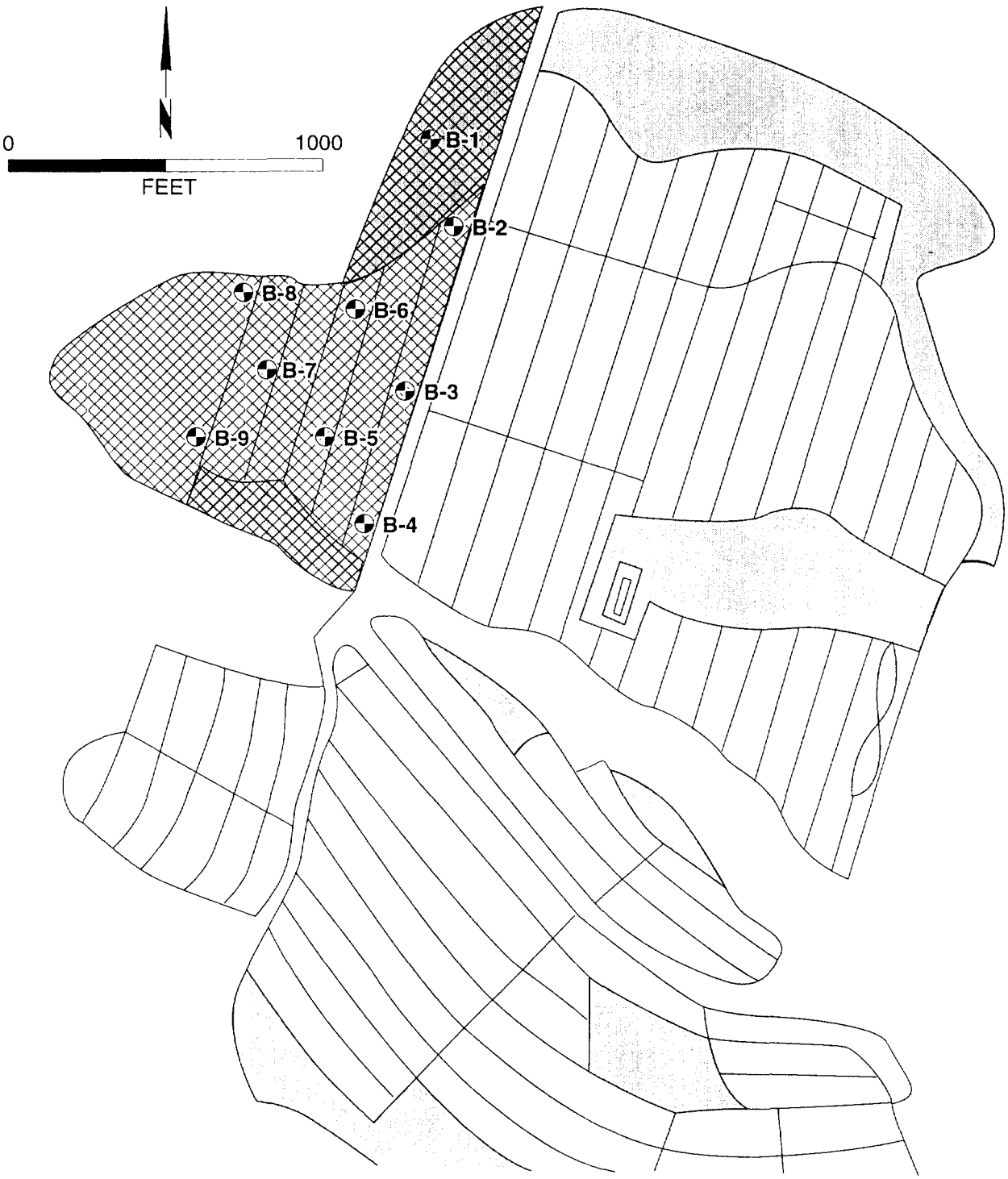
FIGURE **2-13**

**CURRENT SOIL FUMIGANT STORAGE AREA PHOTOGRAPHS**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 983-1532-4000 DRAWING NO. 76310 DATE 4/22/98 DRAWN BY EA

**Golder Associates**




LEGEND

- B-9 Sample Locations
- Grass
- Exavation Pit Soils

FIGURE **2-14**

**EXCAVATION PIT SOIL NATURAL ATTENUATION AREA IN FIELD 8**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 80897 DATE 11/10/98 DRAWN BY EA

**Golder Associates**

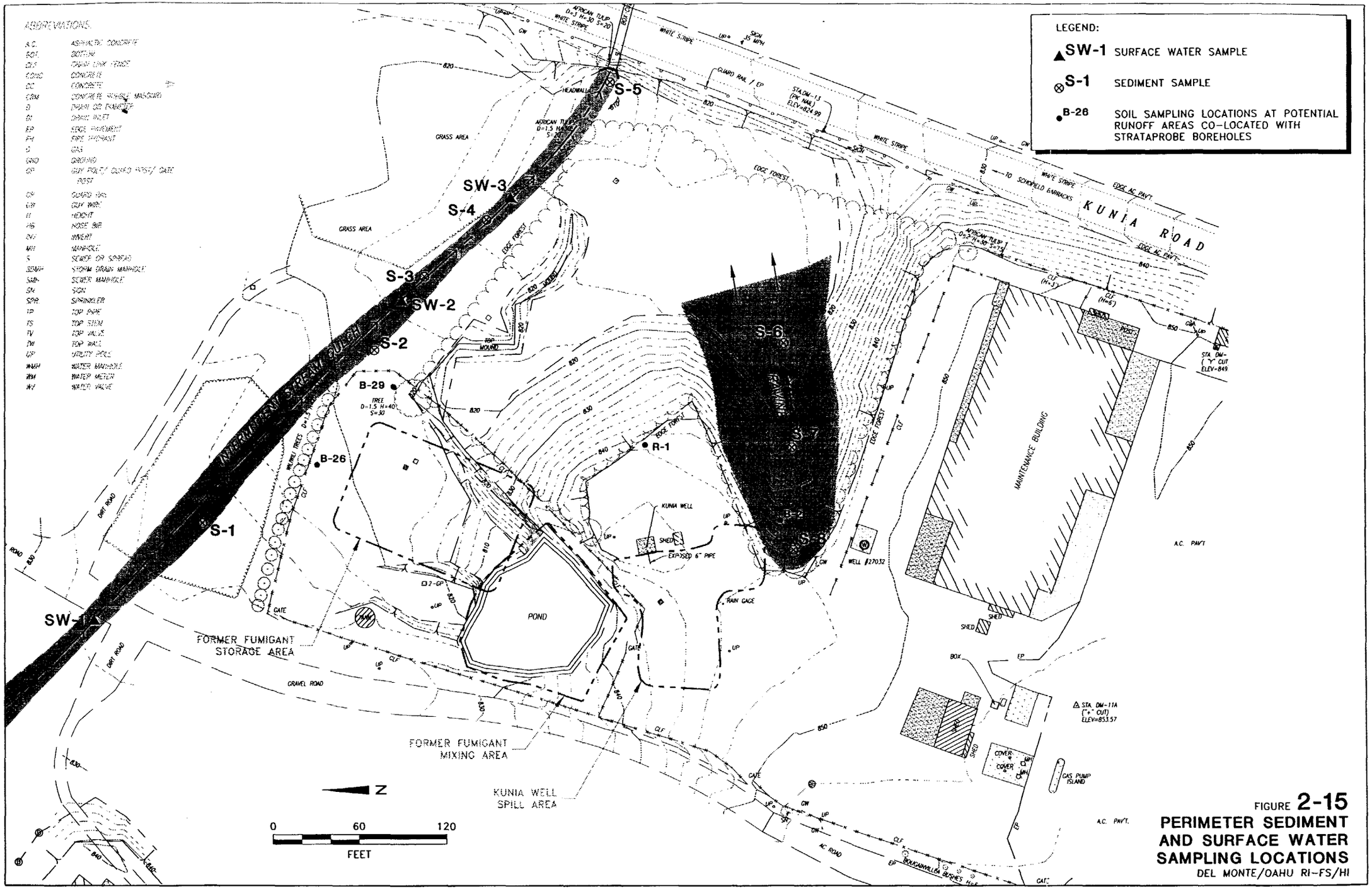



FIGURE 2-15
**PERIMETER SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69911.dwg | 10-9-98 15:12 | xrf:Xbase

**Golder Associates**

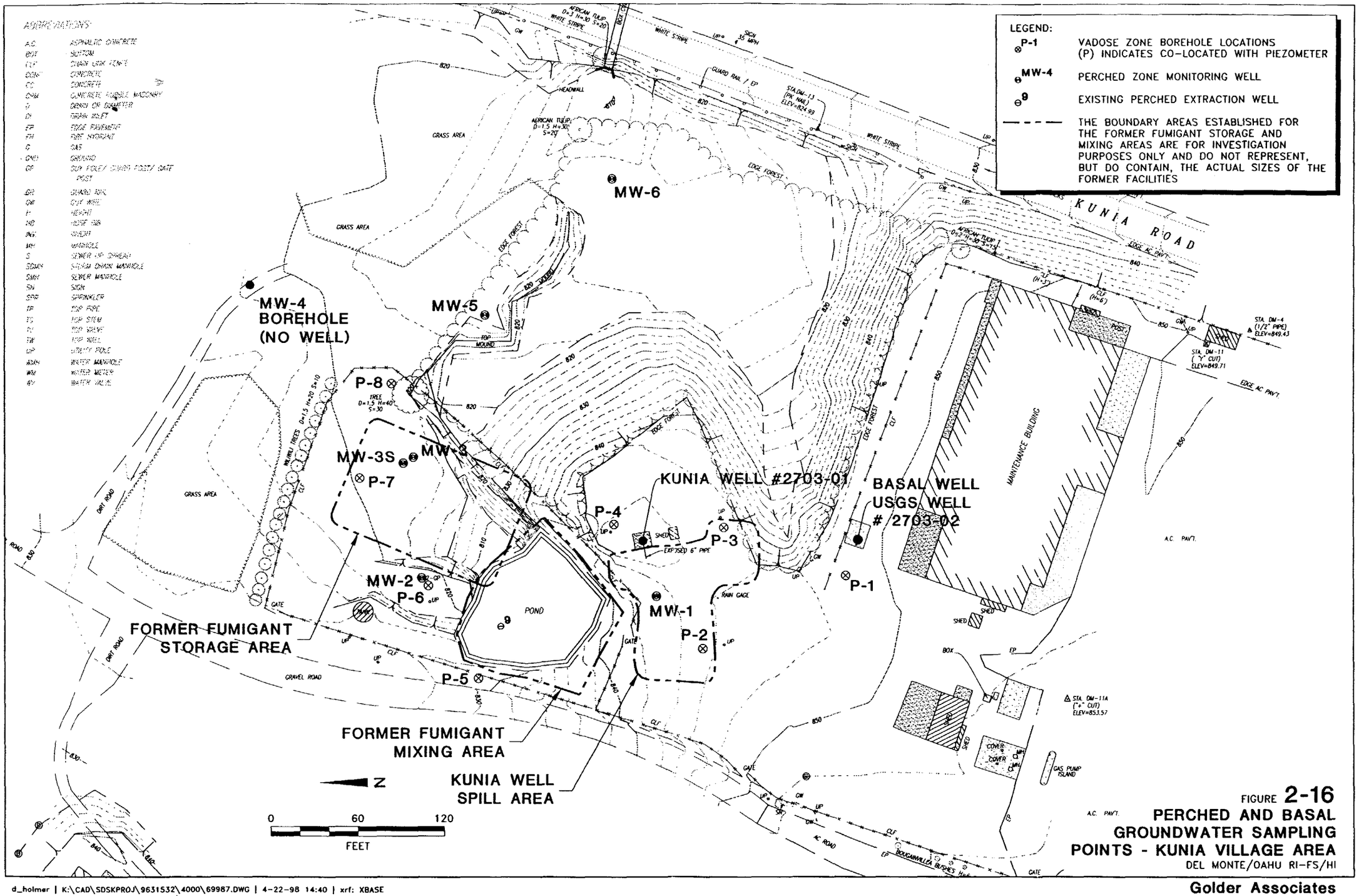
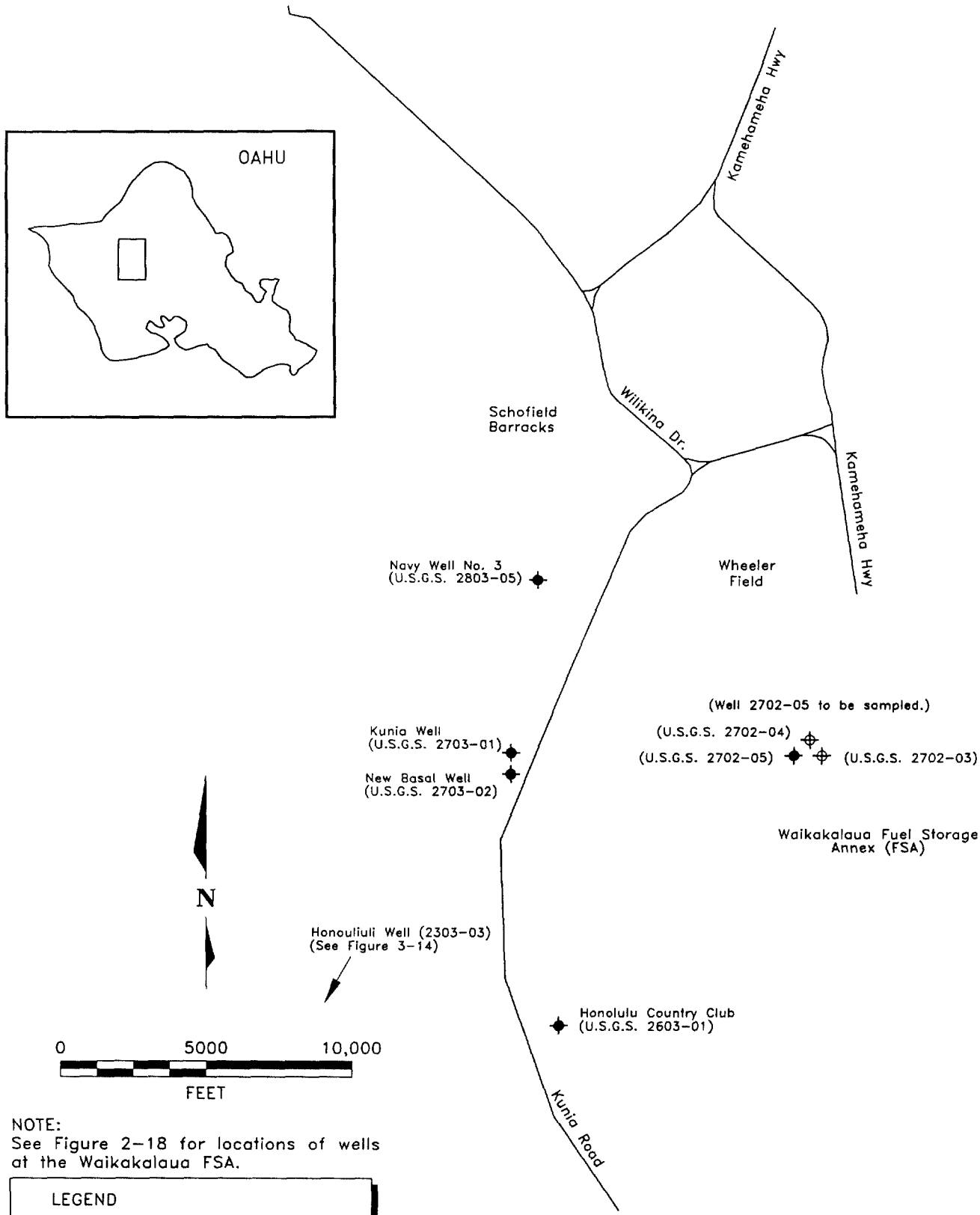



FIGURE 2-16
**PERCHED AND BASAL GROUNDWATER SAMPLING POINTS - KUNIA VILLAGE AREA**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69987.DWG | 4-22-98 14:40 | xrf: XBASE

**Golder Associates**




NOTE:
See Figure 2-18 for locations of wells at the Waikakalaua FSA.

LEGEND

- Basal Well
- Basal Groundwater Sampling Wells

Reference: ICF Technology 1996

FIGURE **2-17**

**BASAL WELLS INCLUDED IN THE RI GROUNDWATER SAMPLING**

DEL MONTE/OAHU RI-FS/HI

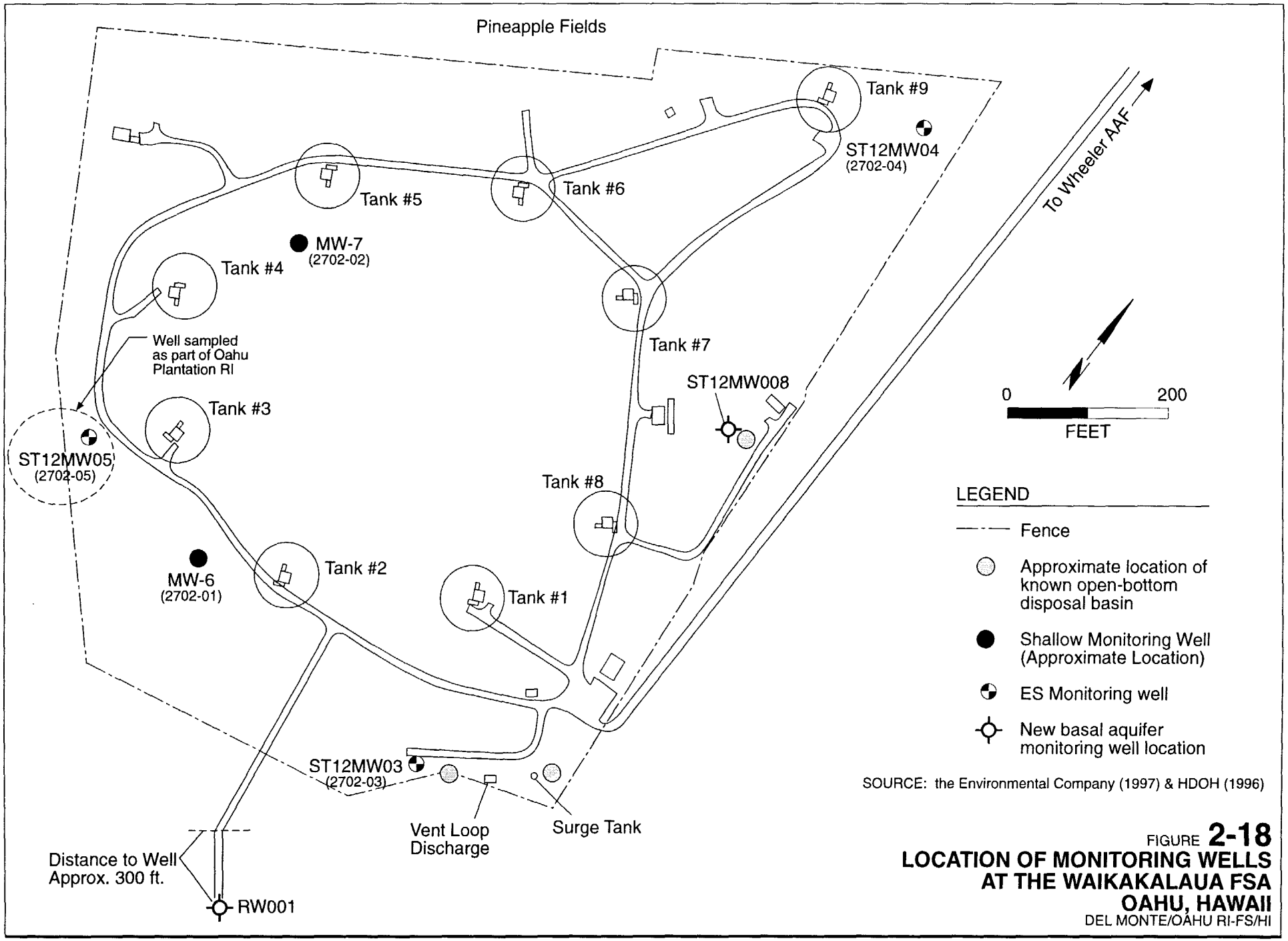


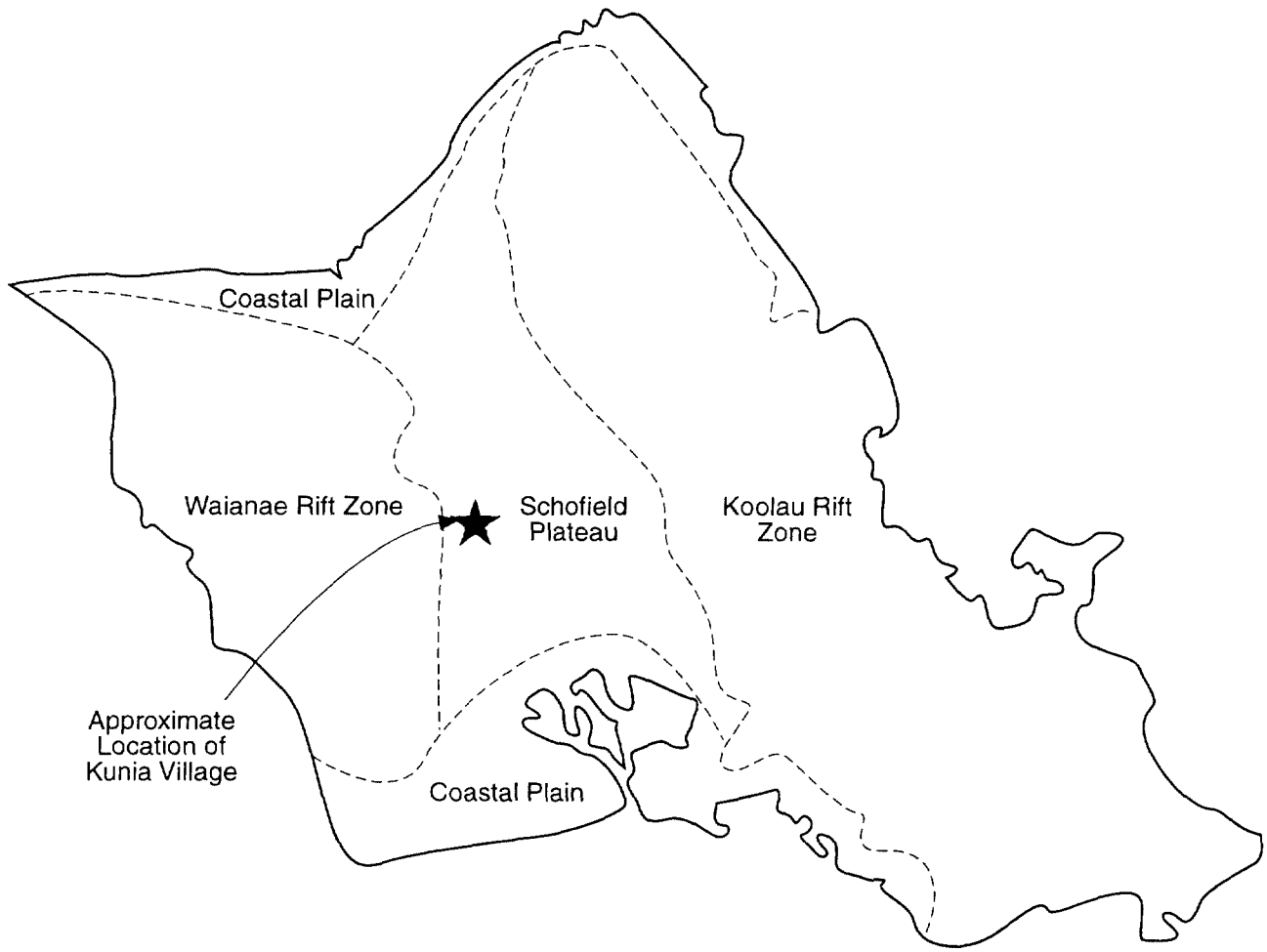

FIGURE **2-18**

**LOCATION OF MONITORING WELLS AT THE WAIKAKALAUA FSA OAHU, HAWAII**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 80898 DATE 10/9/98 DRAWN BY EA

**Golder Associates**



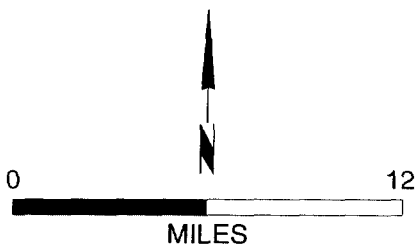



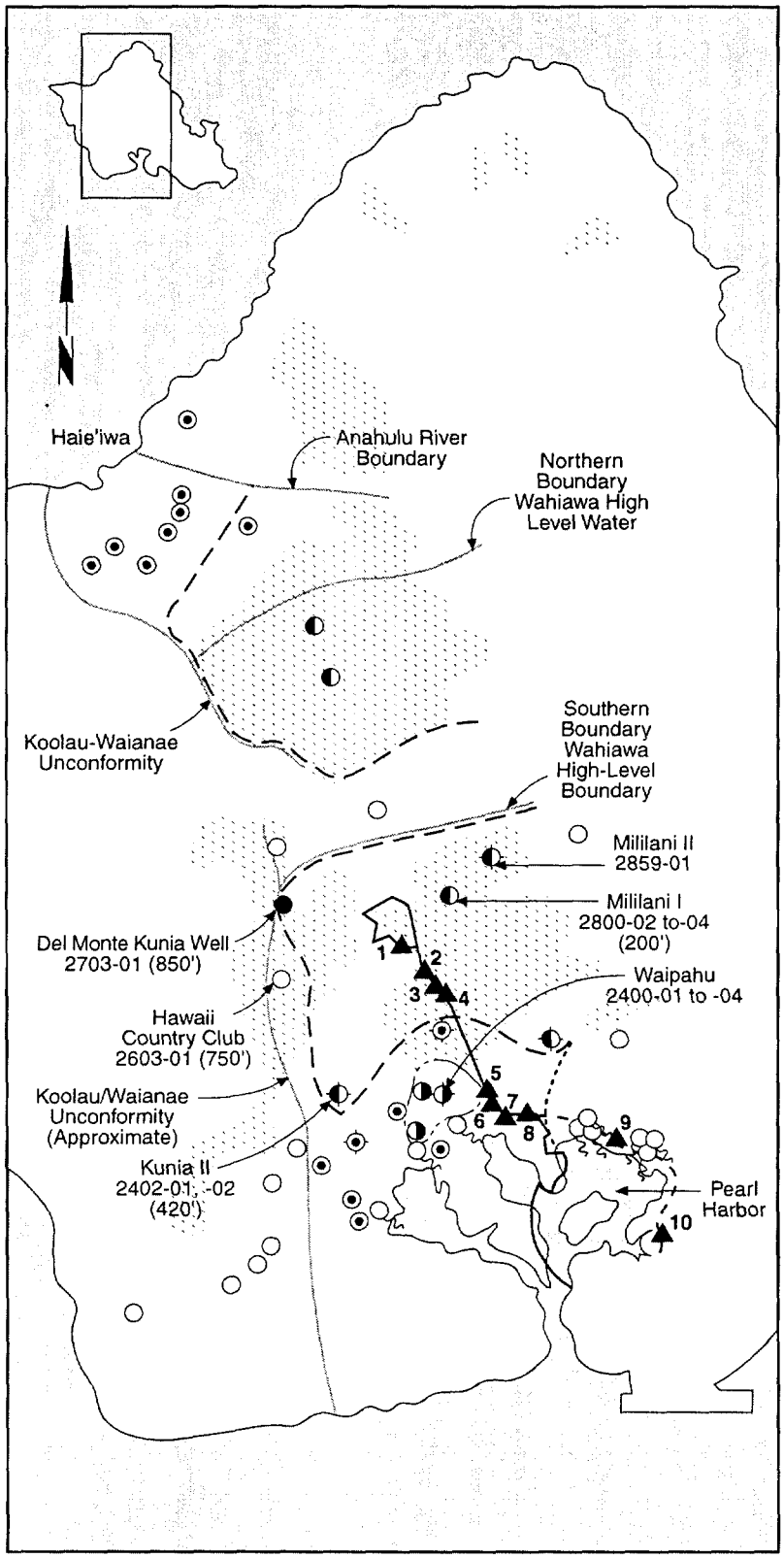

FIGURE **3-1**

**LOCATION OF THE WAIANAE AND KOOLAU RIFT ZONES ON OAHU**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76349 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




SOURCE: Modified from Lau & Mink (1987).

**PIPELINE LEAKS**

| Site Year | Avg. Gas Loss (gal) |
|---|---|
| 1 – 1954 | 70,000 |
| 2 – 1978 | 50,000* |
| 3 – 1957-58 | 15,000 |
| 4 – 1954 | 20,000 |
| 5 – 1954 | 86,000 |
| 6 – 1954 | 300,000 |
| 7 – 1955 | 15,000 |
| 8 – 1951 | 10,000 |
| 9 – 1954 | 20,000 |
| 10 – 1954 | 22,0000 |

* JP-4 (jet fuel)

**LEGEND**

- ▲ Spill Sites
- Pipeline
- Discontinued Fuel Pipeline
- EDB Area (includes TCP) Associated with pipeline fuel leaks
- DBCP Area (includes TCP)
- Approximate Geologic Unconformities
- No TCP, DBCP or EDB Detected East of Line
- Pineapple Fields (Approximate)
- ( ) Elevation

**Wells**

- No Contaminants Detected
- TCP Detected
- DBCP, TCP Detected
- EDB, TCP Detected
- TCP, DBCP, EDB Detected
- Sampled by agencies other than WRRC

**Springs**

- No Chemicals Detected
- EDB, TCP Detected

**NOTE**

Figure shows approximate areas of impacted groundwater as of 1987.

0 2.5 5
SCALE IN MILES

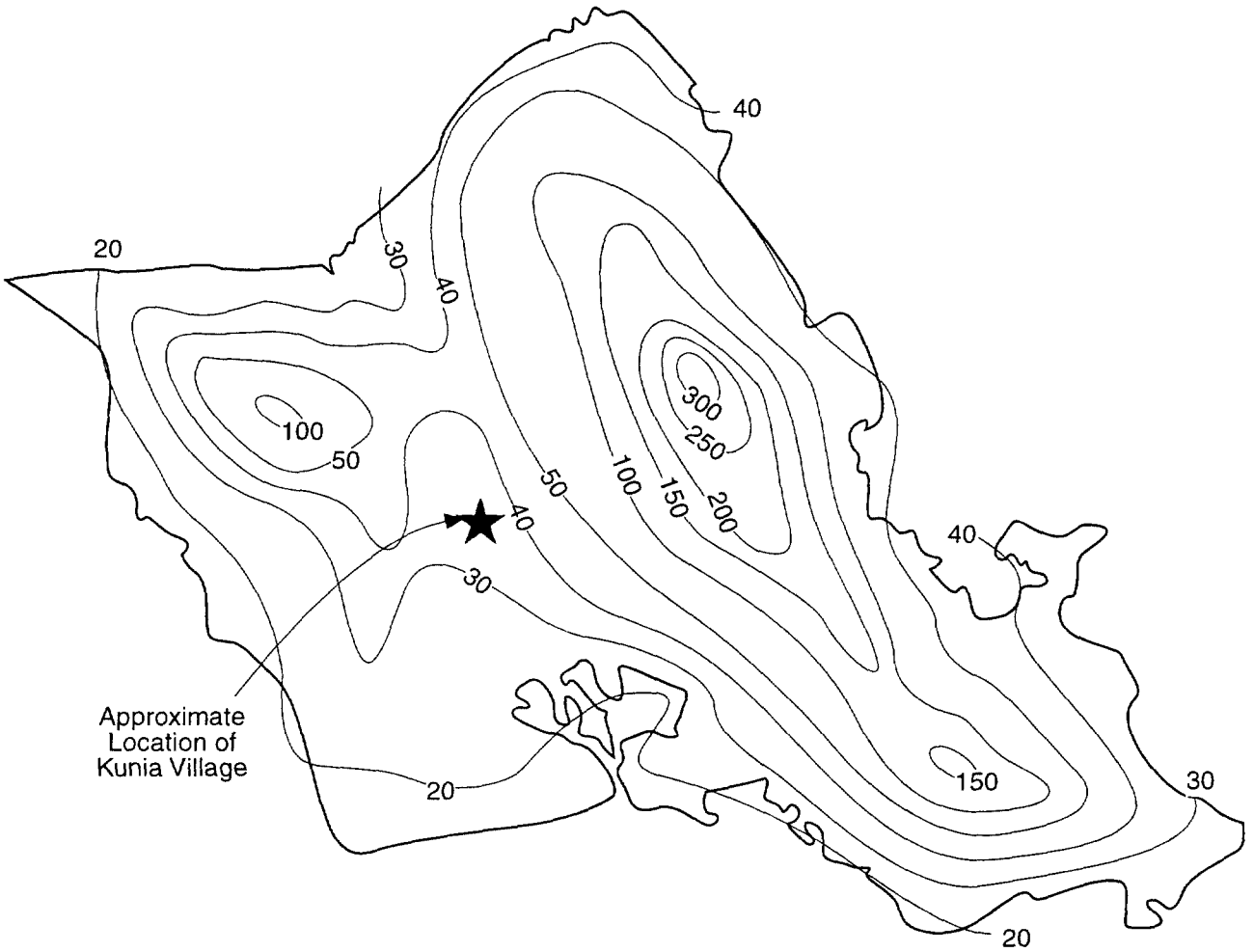
FIGURE **3-2**

**HISTORICAL SPATIAL DISTRIBUTION OF ORGANIC CHEMICAL IMPACTS TO BASAL GROUNDWATER**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 77137 DATE 3/23/98 DRAWN BY TK

**Golder Associates**



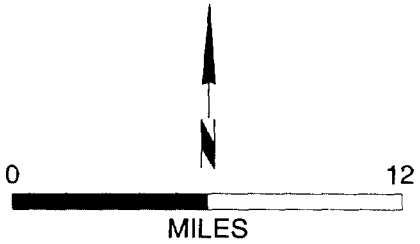




FIGURE **3-3**

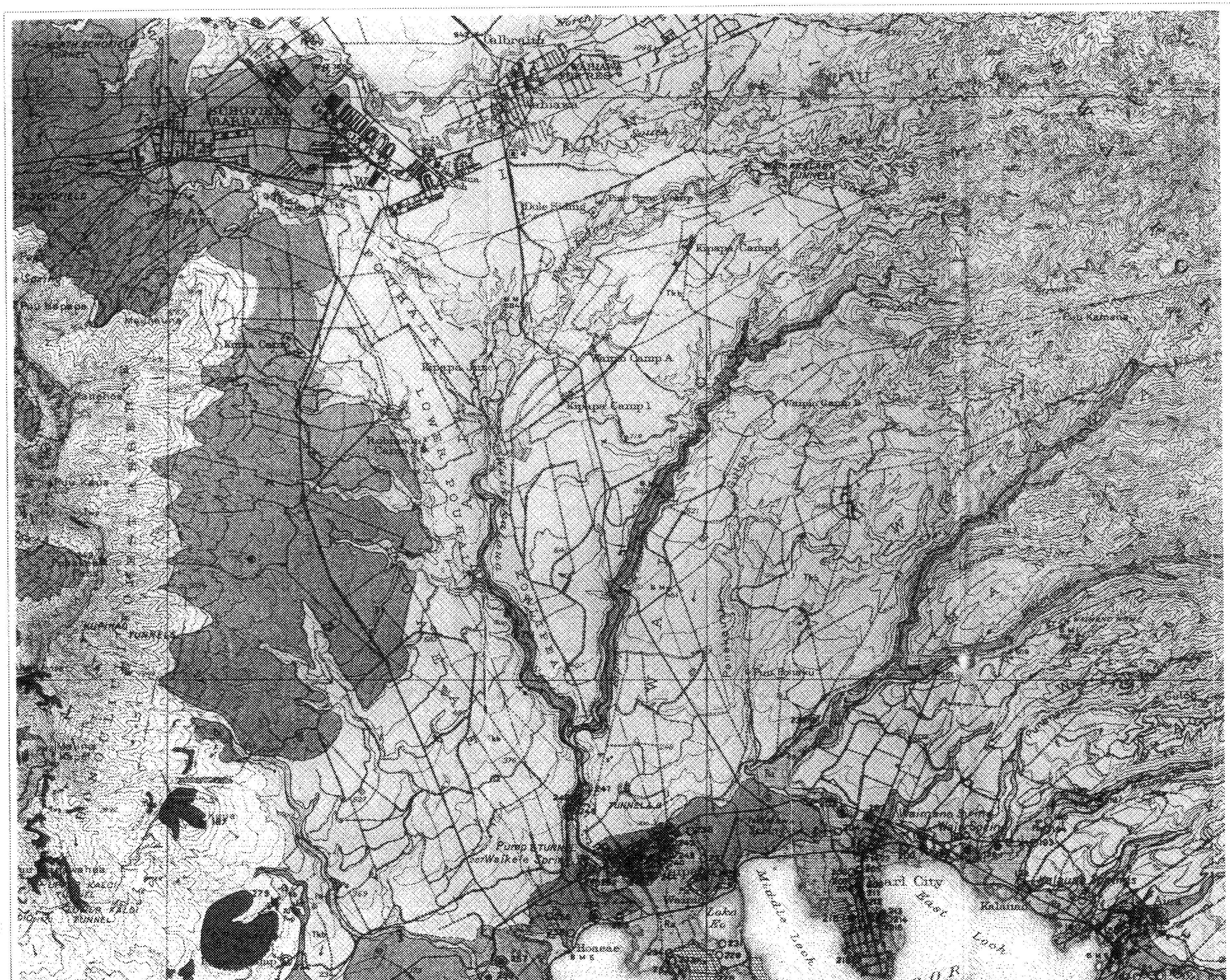
**DISTRIBUTION OF RAINFALL (INCHES) ON OAHU, HAWAII**

DEL MONTE/OAHU RI-FS/HI

Source: Visher and Mink (1964).

PROJECT NO. 963 1532.4000 DRAWING NO. 77007 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




0 — 2
MILES

Source: Stearns, 1939.

LEGEND

- Pa — Consolidated Non-calcareous Deposits
- Tkb — Koolau Volcanic Series
- Twb — Waianae Volcanic Series

FIGURE **3-4**
**GEOLOGIC MAP**
DEL MONTE/OAHU RI-FS/HI

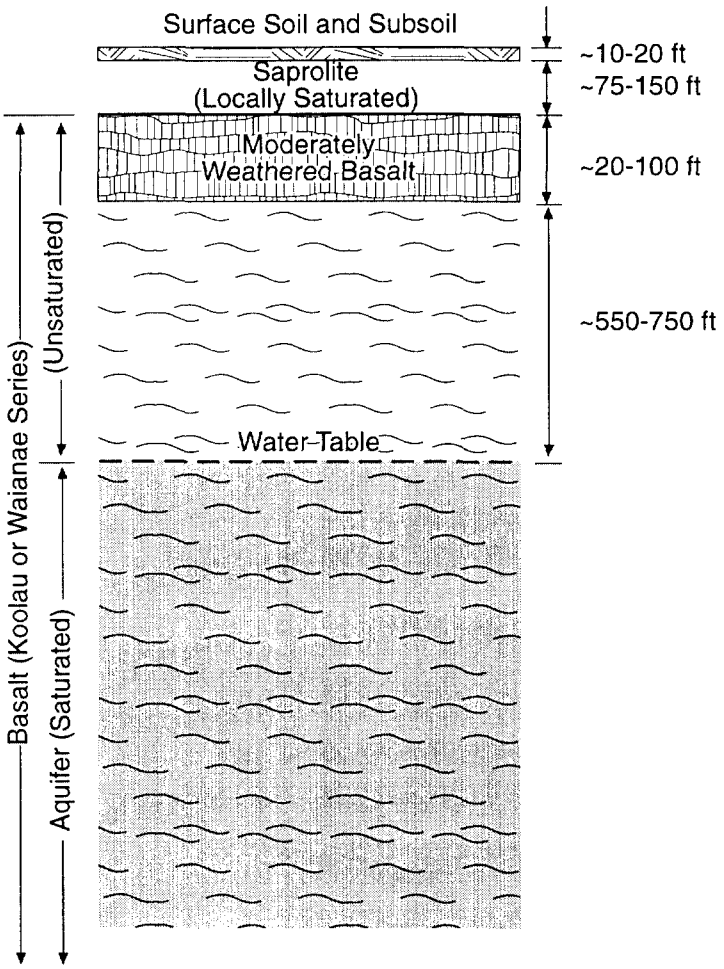



FIGURE **3-5**

**GENERALIZED GEOLOGIC CROSS SECTION OF THE CENTRAL OAHU AREA**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76354 DATE 5/5/98 DRAWN BY EA

**Golder Associates**

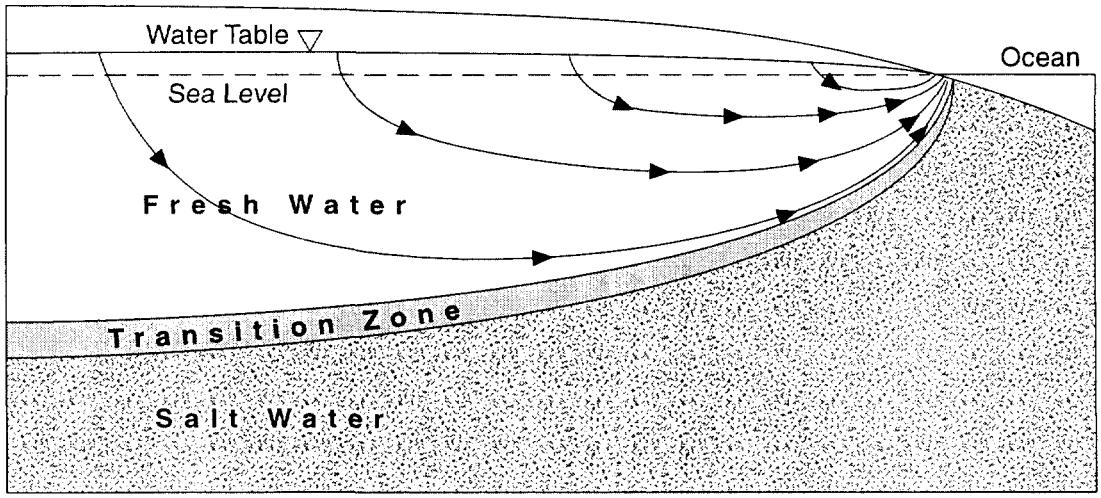



FIGURE **3-6**

**CROSS-SECTIONAL SCHEMATIC OF GROUNDWATER FLOW IN A GHYBEN-HERZBERG LENS**

DEL MONTE/OAHU RI-FS/HI

Source: Modified from Visher and Mink (1964)

PROJECT NO. 963 1532.4000 DRAWING NO 76355 DATE 3/23/98 DRAWN BY EA

**Golder Associates**

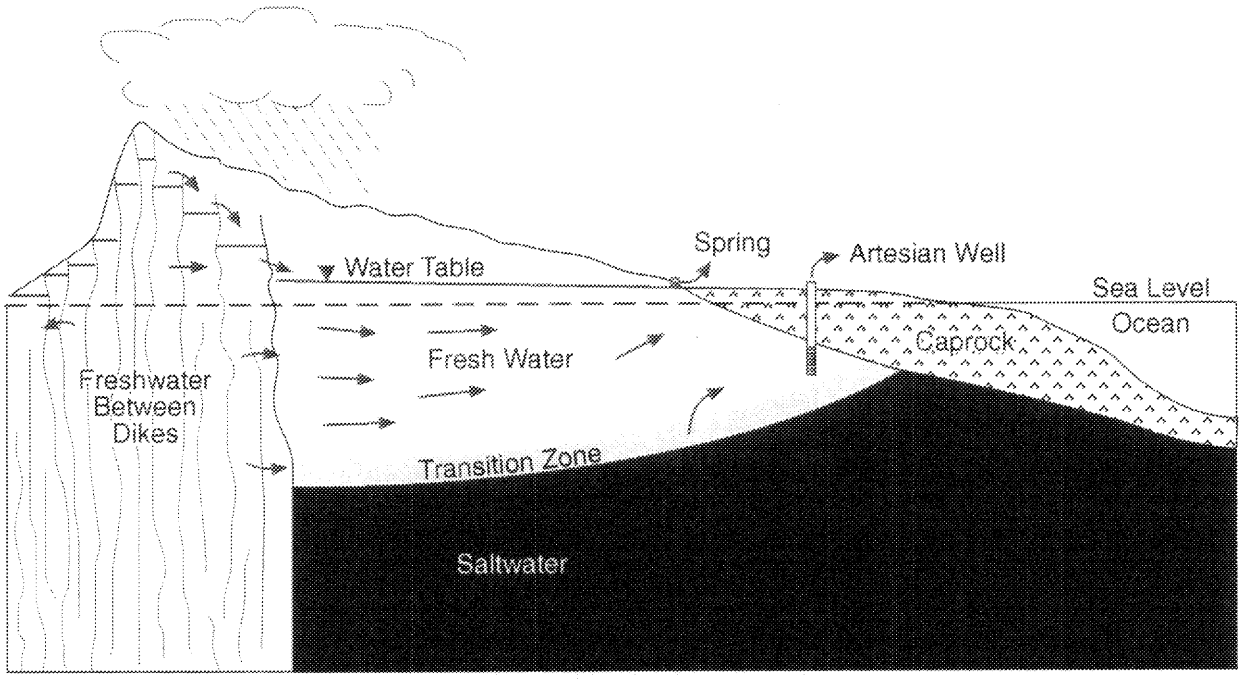



FIGURE **3-7**

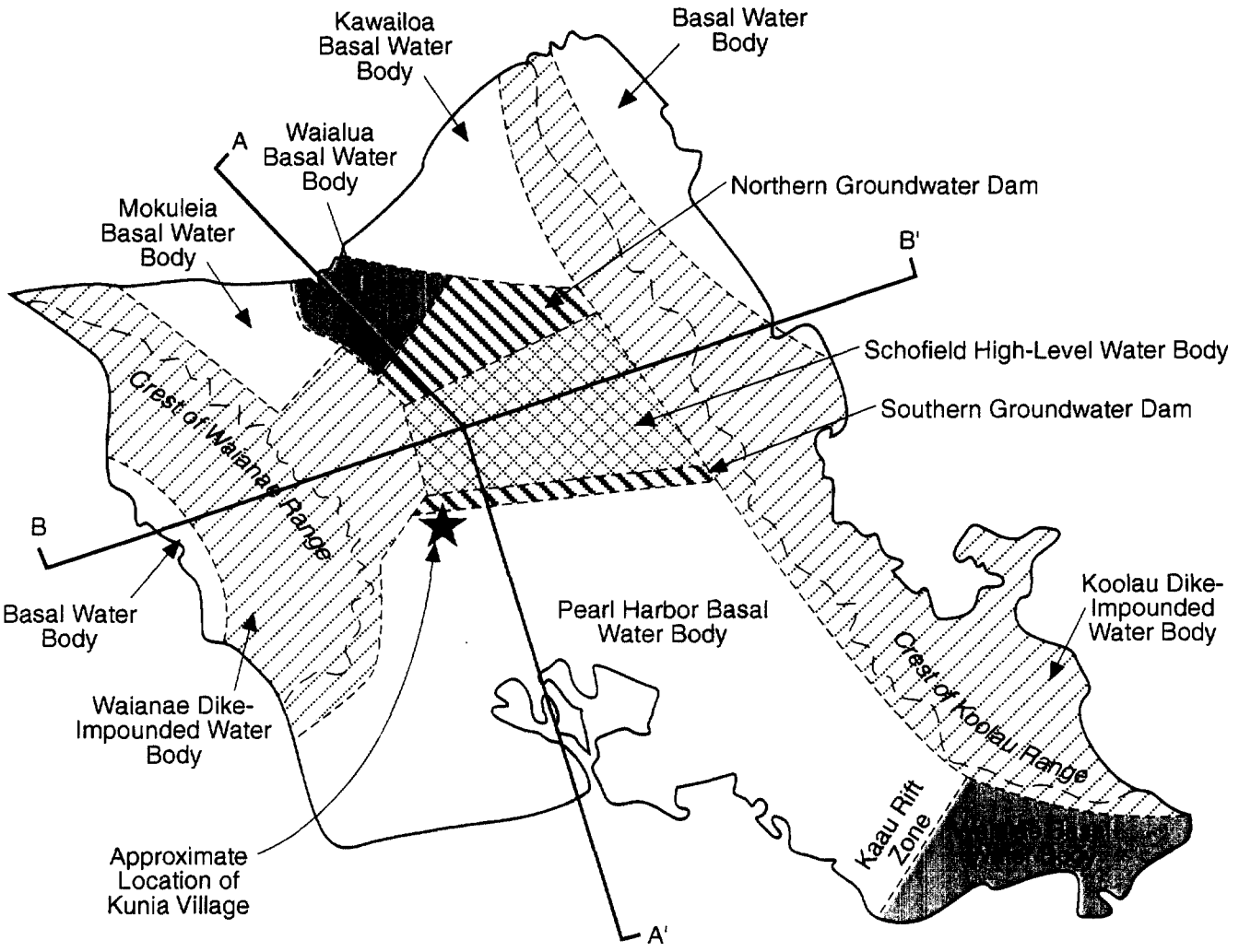
**TYPICAL CROSS-SECTION OF BASAL AND DIKE-IMPOUNDED WATER BODIES SHOWING OCCURRENCE AND MOVEMENT OF GROUNDWATER**

DEL MONTE/OAHU RI-FS/HI

Source: Modified from Souza and Voss (1987).

PROJECT NO. 983 1532.4000 DRAWING NO. 76356 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




LEGEND

- Boundary Between Groundwater Bodies
- Basal Water Body
- Schofield High-Level Water Body
- Dike-Impounded Water Body
- Goundwater Dam
- A A' Generalized Cross Section Line

N

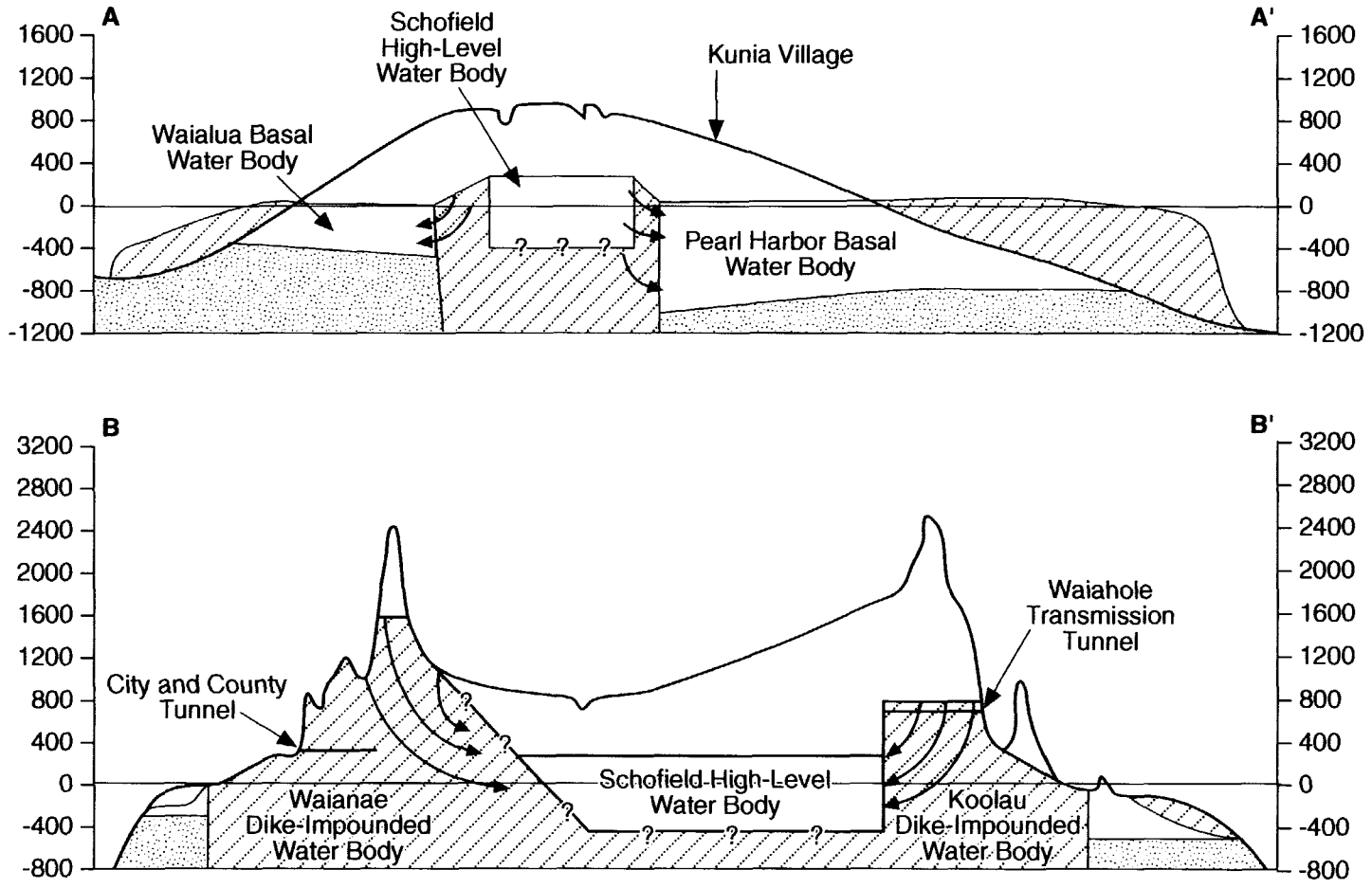
0 12
MILES

Source: Modified from Dale and Takasaki (1976) and Mink and Lau (1990). Cross sections are shown on Figure 3-9.

FIGURE **3-8**
**REGIONAL GROUNDWATER SYSTEMS OF OAHU, HAWAII**
DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76351 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




LEGEND

- Low-Permeability Rock
- Fresh Groundwater
- Saline Groundwater
- Groundwater Flow Line (generalized direction)

N

0 6
MILES

Source: Modified from Dale and Takasaki (1976).

FIGURE **3-9**
**REGIONAL HYDROGEOLOGIC CROSS SECTIONS A-A' AND B-B'**
DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76357 DATE 3/23/98 DRAWN BY EA

**Golder Associates**

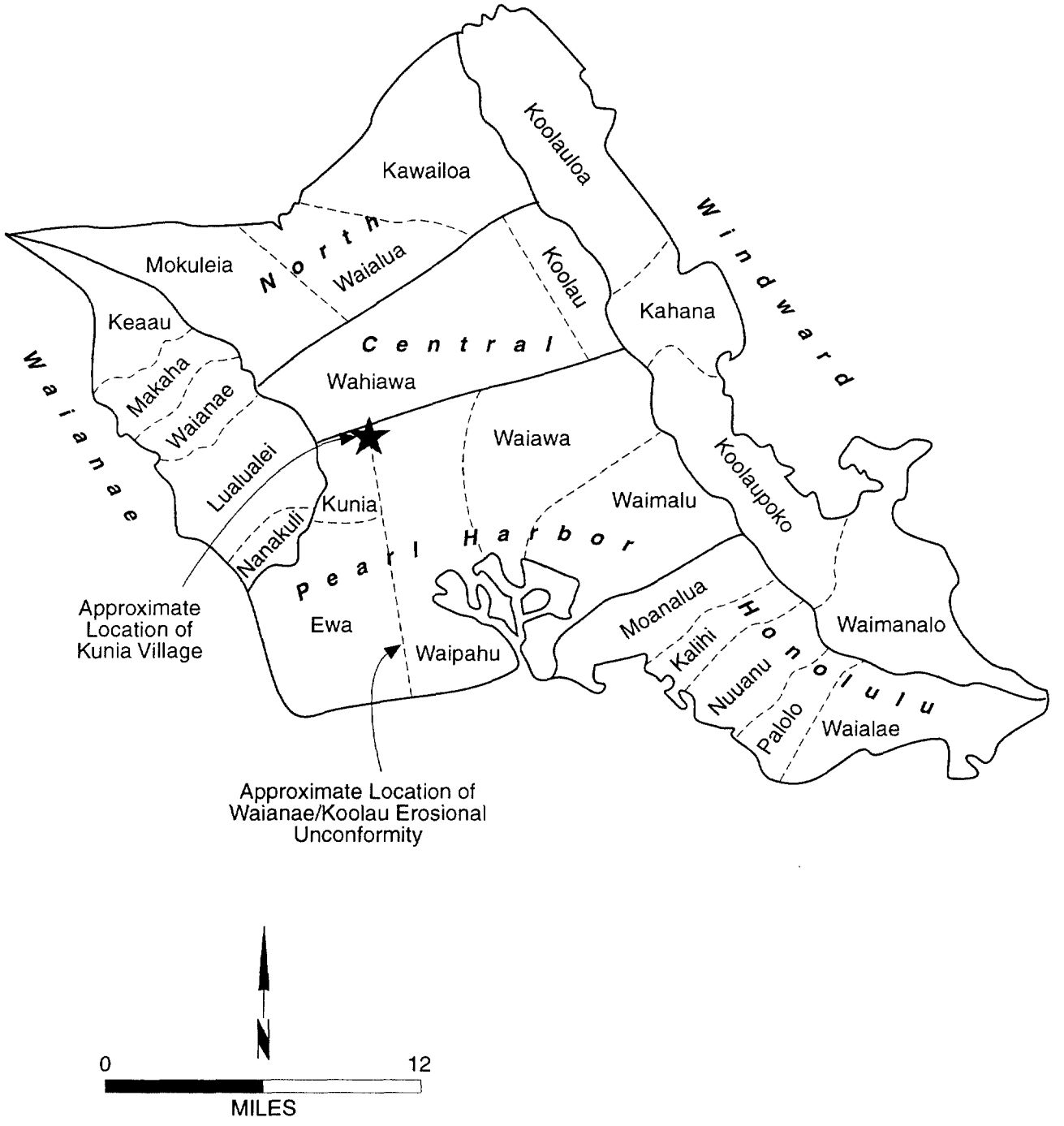
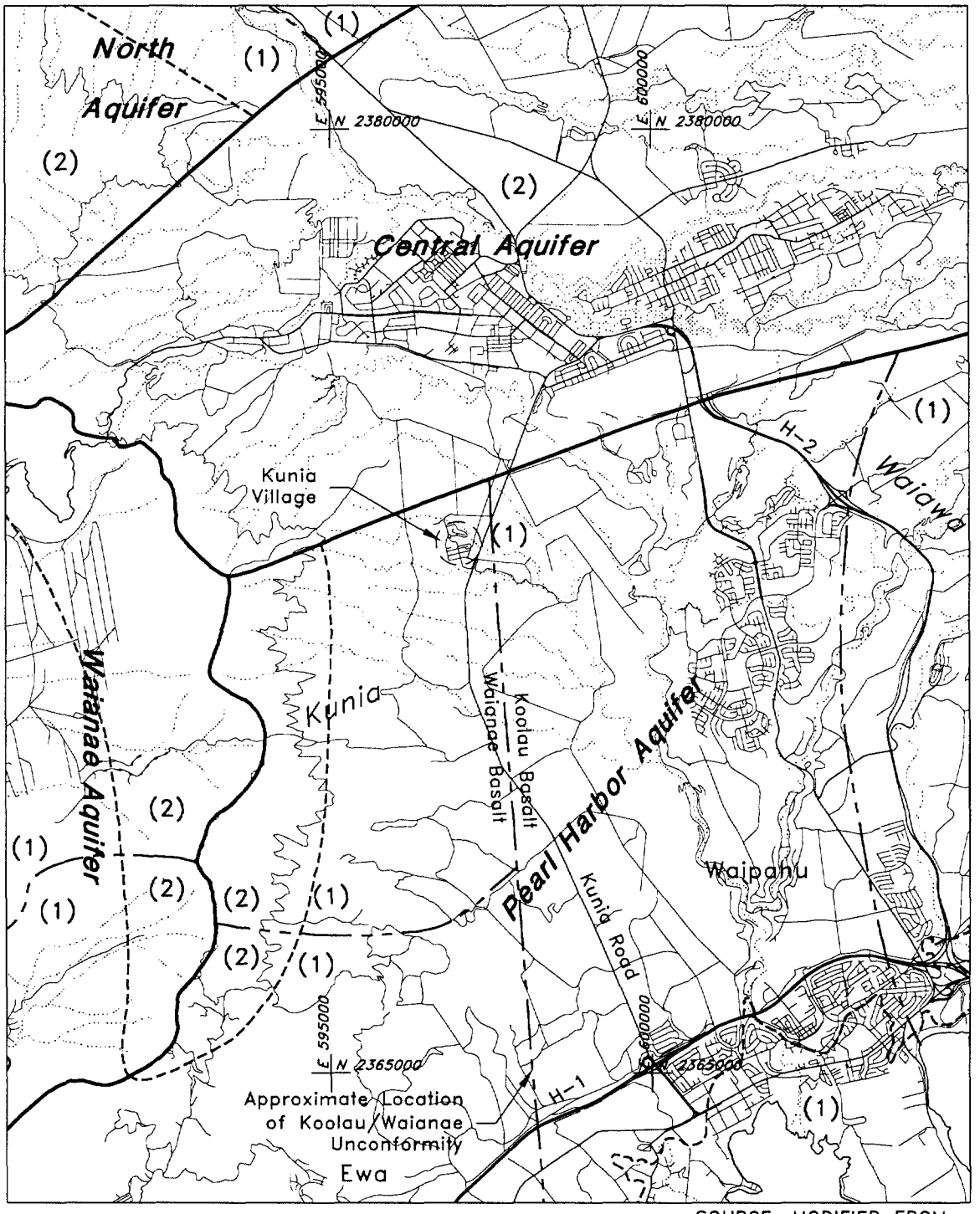



FIGURE **3-10**
**LAYOUT OF AQUIFER SECTORS AND SYSTEMS FOR OAHU**
DEL MONTE/OAHU RI-FS/HI

Source: Modified from Mink and Lau (1990).

PROJECT NO. 963 1532.4000 DRAWING NO. 76352 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




N

LEGEND:

AQUIFER SECTOR BOUNDARY

AQUIFER SYSTEM BOUNDARY

AQUIFER TYPE BOUNDARY

***North Aquifer*** AQUIFER SECTOR NAME

*Kunia* AQUIFER SYSTEM NAME

(1) BASAL AQUIFER TYPE

(2) HIGH-LEVEL AQUIFER TYPE

SOURCE: MODIFIED FROM MINK & LAU (1990)

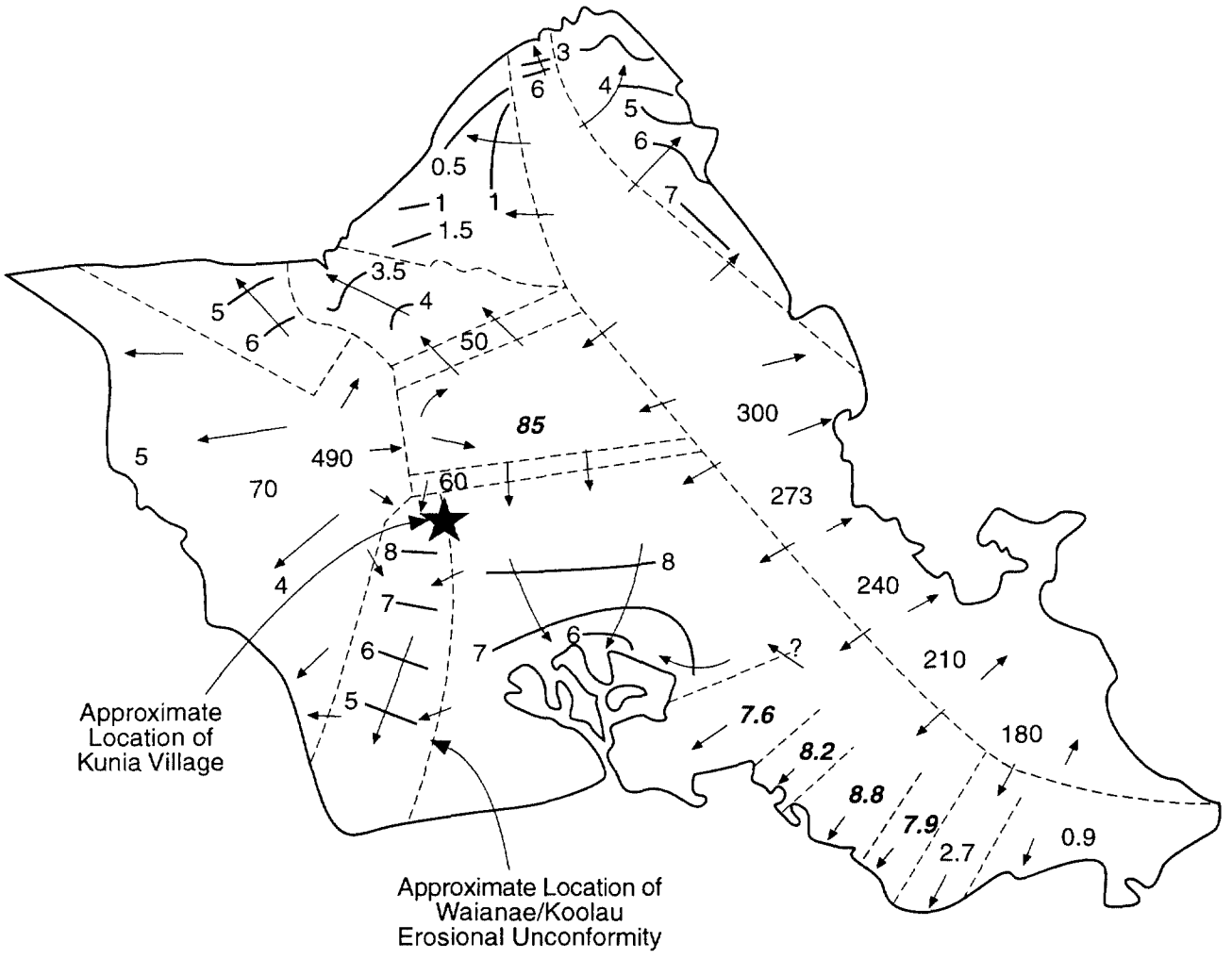
0 3000 6000 METERS

0 10000 20000 FEET

FIGURE **3-11**

**AQUIFER BOUNDARIES**

DEL MONTE/OAHU/HI




LEGEND

| | |
|---|---|
| 6 | Water level contour, in meters above mean sea level (contour interval variable) |
| 85 | Point observation of water level, in meters above mean sea level |
| *7.6* | Representative water level where water table is too flat to be contoured, in meters above mean sea level |
| → | Generalized direction of groundwater flow |

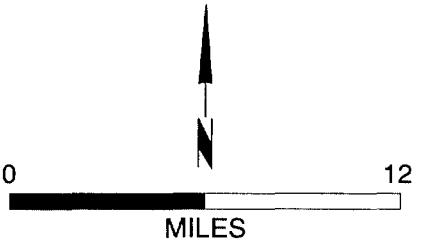



FIGURE **3-12**

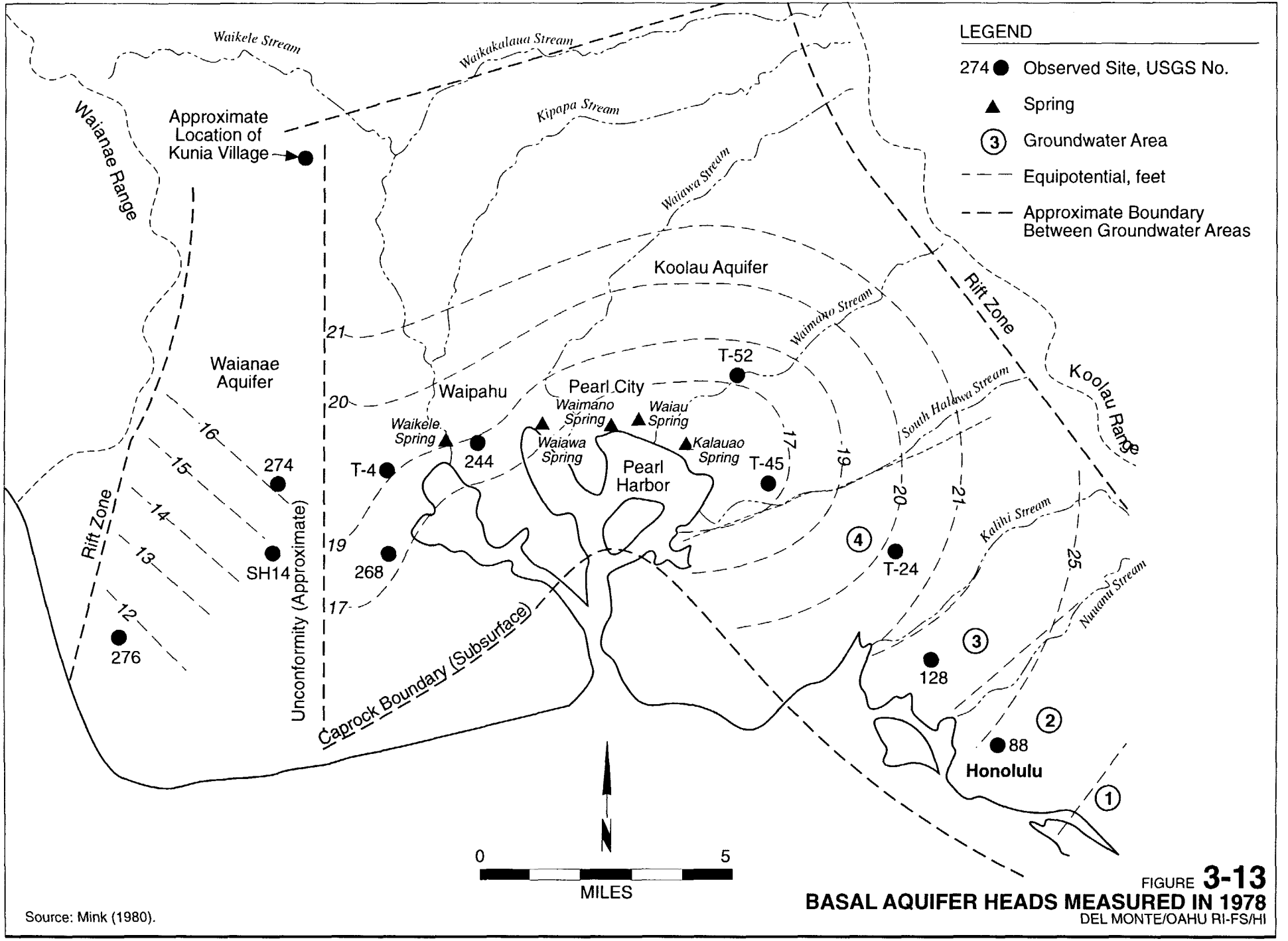
**WATER LEVELS IN PRINCIPAL OAHU AQUIFERS AND INFERRED FRESHWATER FLOW DIRECTIONS**

DEL MONTE/OAHU RI-FS/HI

Source: Voss and Wood (1993), and Oki (1998).

PROJECT NO. 963 1532.4000 DRAWING NO. 76350 DATE 5/5/98 DRAWN BY EA

**Golder Associates**




Source: Mink (1980).

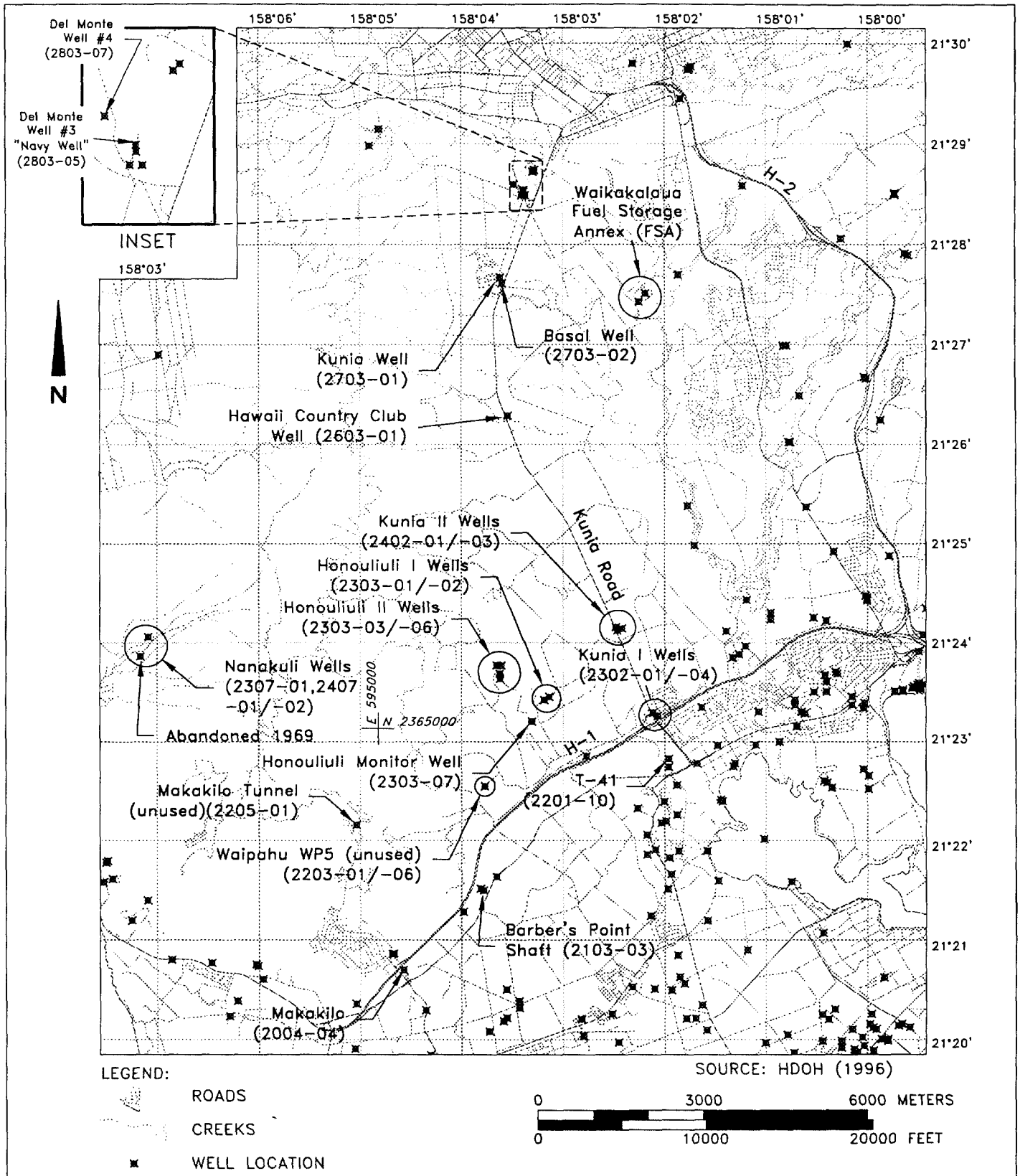
FIGURE **3-13**

**BASAL AQUIFER HEADS MEASURED IN 1978**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 76353 DATE 5/5/98 DRAWN BY EA

**Golder Associates**




NOTES:

1) Identified wells represent locations considered most relevant to this RI due to their use and/or location.
2) See Table 3-6 for well construction information on highlighted wells.
3) See Figure 2-18 for location of wells in the Waikakalaua FSA.
4) Latitudes and longitudes are approximate.

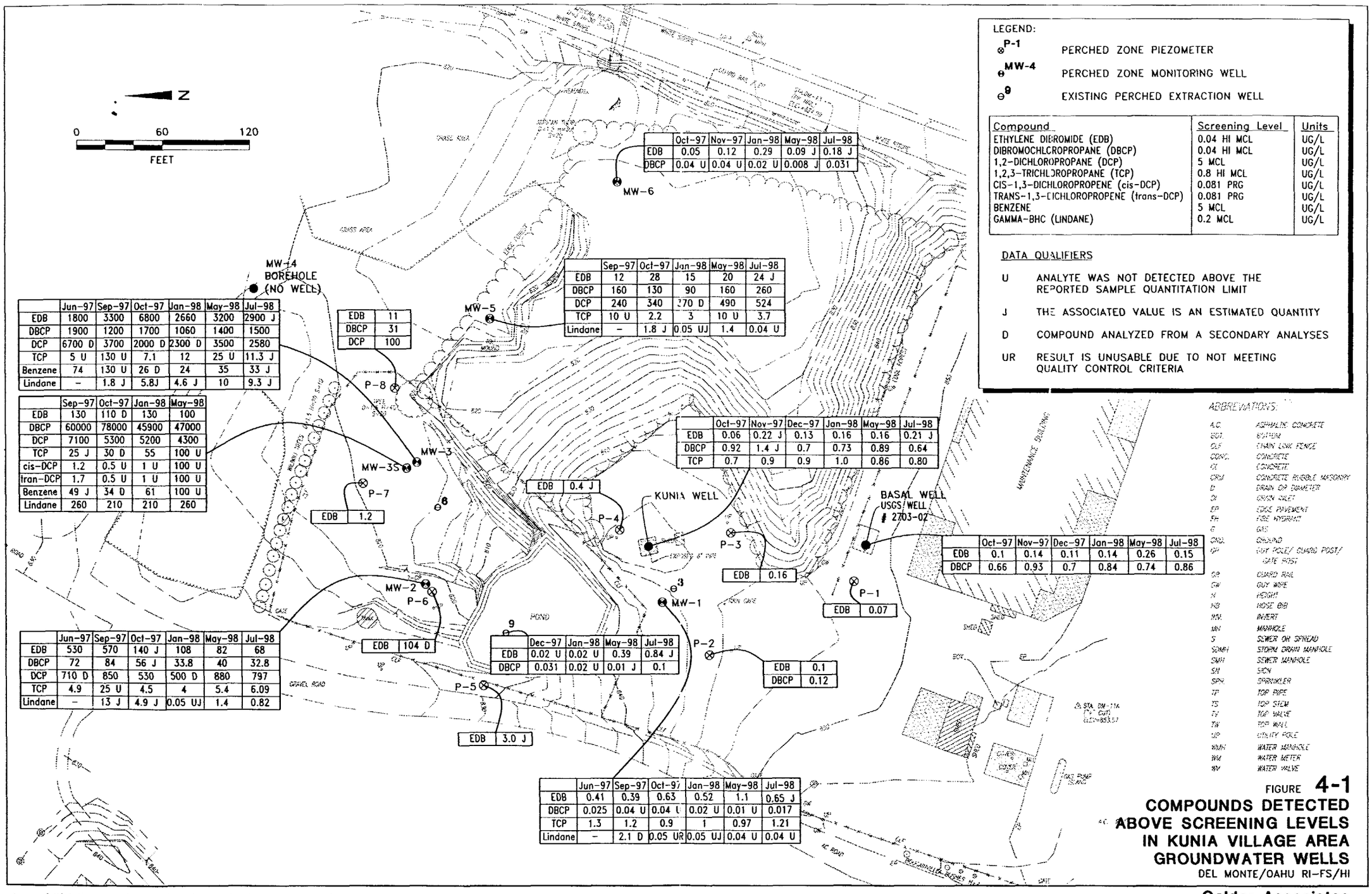
FIGURE **3-14**

**REGIONAL WELL LOCATIONS**

DEL MONTE/OAHU/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69868.DWG | 10-13-98 9:16 | xrf: NO

**Golder Associates**




| Compound | Screening Level | Units |
|---|---|---|
| ETHYLENE DIBROMIDE (EDB) | 0.04 HI MCL | UG/L |
| DIBROMOCHLOROPROPANE (DBCP) | 0.04 HI MCL | UG/L |
| 1,2-DICHLOROPROPANE (DCP) | 5 MCL | UG/L |
| 1,2,3-TRICHLOROPROPANE (TCP) | 0.8 HI MCL | UG/L |
| CIS-1,3-DICHLOROPROPENE (cis-DCP) | 0.081 PRG | UG/L |
| TRANS-1,3-DICHLOROPROPENE (trans-DCP) | 0.081 PRG | UG/L |
| BENZENE | 5 MCL | UG/L |
| GAMMA-BHC (LINDANE) | 0.2 MCL | UG/L |

| | Oct-97 | Nov-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|
| EDB | 0.05 | 0.12 | 0.29 | 0.09 J | 0.18 J |
| DBCP | 0.04 U | 0.04 U | 0.02 U | 0.008 J | 0.031 |

| | Sep-97 | Oct-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|
| EDB | 12 | 28 | 15 | 20 | 24 J |
| DBCP | 160 | 130 | 90 | 160 | 260 |
| DCP | 240 | 340 | 270 D | 490 | 524 |
| TCP | 10 U | 2.2 | 3 | 10 U | 3.7 |
| Lindane | – | 1.8 J | 0.05 UJ | 1.4 | 0.04 U |

| | Jun-97 | Sep-97 | Oct-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|---|
| EDB | 1800 | 3300 | 6800 | 2660 | 3200 | 2900 J |
| DBCP | 1900 | 1200 | 1700 | 1060 | 1400 | 1500 |
| DCP | 6700 D | 3700 | 2000 D | 2300 D | 3500 | 2580 |
| TCP | 5 U | 130 U | 7.1 | 12 | 25 U | 11.3 J |
| Benzene | 74 | 130 U | 26 D | 24 | 35 | 33 J |
| Lindane | – | 1.8 J | 5.8J | 4.6 J | 10 | 9.3 J |

| | |
|---|---|
| EDB | 11 |
| DBCP | 31 |
| DCP | 100 |

| | Sep-97 | Oct-97 | Jan-98 | May-98 |
|---|---|---|---|---|
| EDB | 130 | 110 D | 130 | 100 |
| DBCP | 60000 | 78000 | 45900 | 47000 |
| DCP | 7100 | 5300 | 5200 | 4300 |
| TCP | 25 J | 30 D | 55 | 100 U |
| cis-DCP | 1.2 | 0.5 U | 1 U | 100 U |
| tran-DCP | 1.7 | 0.5 U | 1 U | 100 U |
| Benzene | 49 J | 34 D | 61 | 100 U |
| Lindane | 260 | 210 | 210 | 260 |

| | |
|---|---|
| EDB | 1.2 |

| | |
|---|---|
| EDB | 0.4 J |

| | Oct-97 | Nov-97 | Dec-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|---|
| EDB | 0.06 | 0.22 J | 0.13 | 0.16 | 0.16 | 0.21 J |
| DBCP | 0.92 | 1.4 J | 0.7 | 0.73 | 0.89 | 0.64 |
| TCP | 0.7 | 0.9 | 0.9 | 1.0 | 0.86 | 0.80 |

| | |
|---|---|
| EDB | 0.16 |

| | Oct-97 | Nov-97 | Dec-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|---|
| EDB | 0.1 | 0.14 | 0.11 | 0.14 | 0.26 | 0.15 |
| DBCP | 0.66 | 0.93 | 0.7 | 0.84 | 0.74 | 0.86 |

| | |
|---|---|
| EDB | 0.07 |

| | Jun-97 | Sep-97 | Oct-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|---|
| EDB | 530 | 570 | 140 J | 108 | 82 | 68 |
| DBCP | 72 | 84 | 56 J | 33.8 | 40 | 32.8 |
| DCP | 710 D | 850 | 530 | 500 D | 880 | 797 |
| TCP | 4.9 | 25 U | 4.5 | 4 | 5.4 | 6.09 |
| Lindane | – | 13 J | 4.9 J | 0.05 UJ | 1.4 | 0.82 |

| | |
|---|---|
| EDB | 104 D |

| | Dec-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|
| EDB | 0.02 U | 0.02 U | 0.39 | 0.84 J |
| DBCP | 0.031 | 0.02 U | 0.01 J | 0.1 |

| | |
|---|---|
| EDB | 0.1 |
| DBCP | 0.12 |

| | |
|---|---|
| EDB | 3.0 J |

| | Jun-97 | Sep-97 | Oct-97 | Jan-98 | May-98 | Jul-98 |
|---|---|---|---|---|---|---|
| EDB | 0.41 | 0.39 | 0.63 | 0.52 | 1.1 | 0.65 J |
| DBCP | 0.025 | 0.04 U | 0.04 U | 0.02 U | 0.01 U | 0.017 |
| TCP | 1.3 | 1.2 | 0.9 | 1 | 0.97 | 1.21 |
| Lindane | – | 2.1 D | 0.05 UR | 0.05 UJ | 0.04 U | 0.04 U |

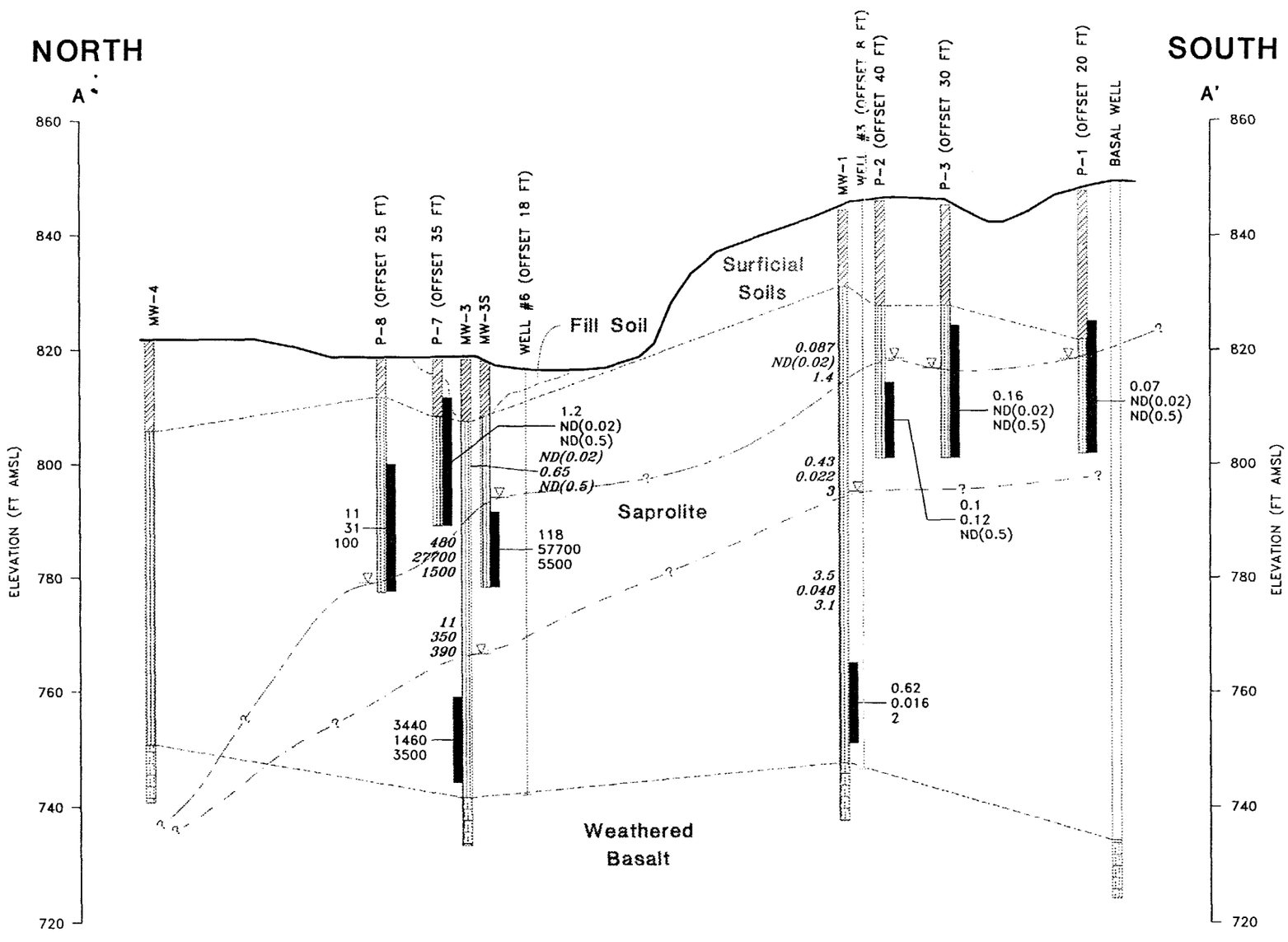
FIGURE **4-1**

**COMPOUNDS DETECTED ABOVE SCREENING LEVELS IN KUNIA VILLAGE AREA GROUNDWATER WELLS**

DEL MONTE/OAHU RI-FS/HI



**Golder Associates**




EXPLANATION:

- 11 / 31 / 100 — SAND PACK INTERVAL WITH EDB, DBCP AND DCP CONCENTRATIONS (μg/L)
- 150 / 200 / 2 — HYDROPUNCH EDB, DBCP AND DCP RESULTS (μg/L)
- ND(0.5) — NOT DETECTED AT THE INDICATED CONCENTRATION
- GROUNDWATER ELEVATION (OCTOBER 1997)
- SOFT TO STIFF, GRAYISH BROWN (5YR 3/2) TO MODERATE BROWN (5YR 4/4), SILTY CLAY (SURFACE SOIL AND SUBSOIL)
- STIFF TO VERY STIFF, MODERATE BROWN TO GRAYISH RED, SILTY CLAY, FRIABLE, WITH MINERAL INFILLED VESICLES, OCCASIONAL WEATHERED BASALT BOULDERS (SAPROLITE)
- HARD, DARK GREENISH GRAY, WEATHERED BASALT
- POTENTIOMETRIC SURFACE OF THE UPPER PERCHED AQUIFER (OCTOBER 1997)
- POTENTIOMETRIC SURFACE OF THE LOWER PERCHED AQUIFER (OCTOBER 1997)
- GEOLOGIC CONTACT

NOTES:

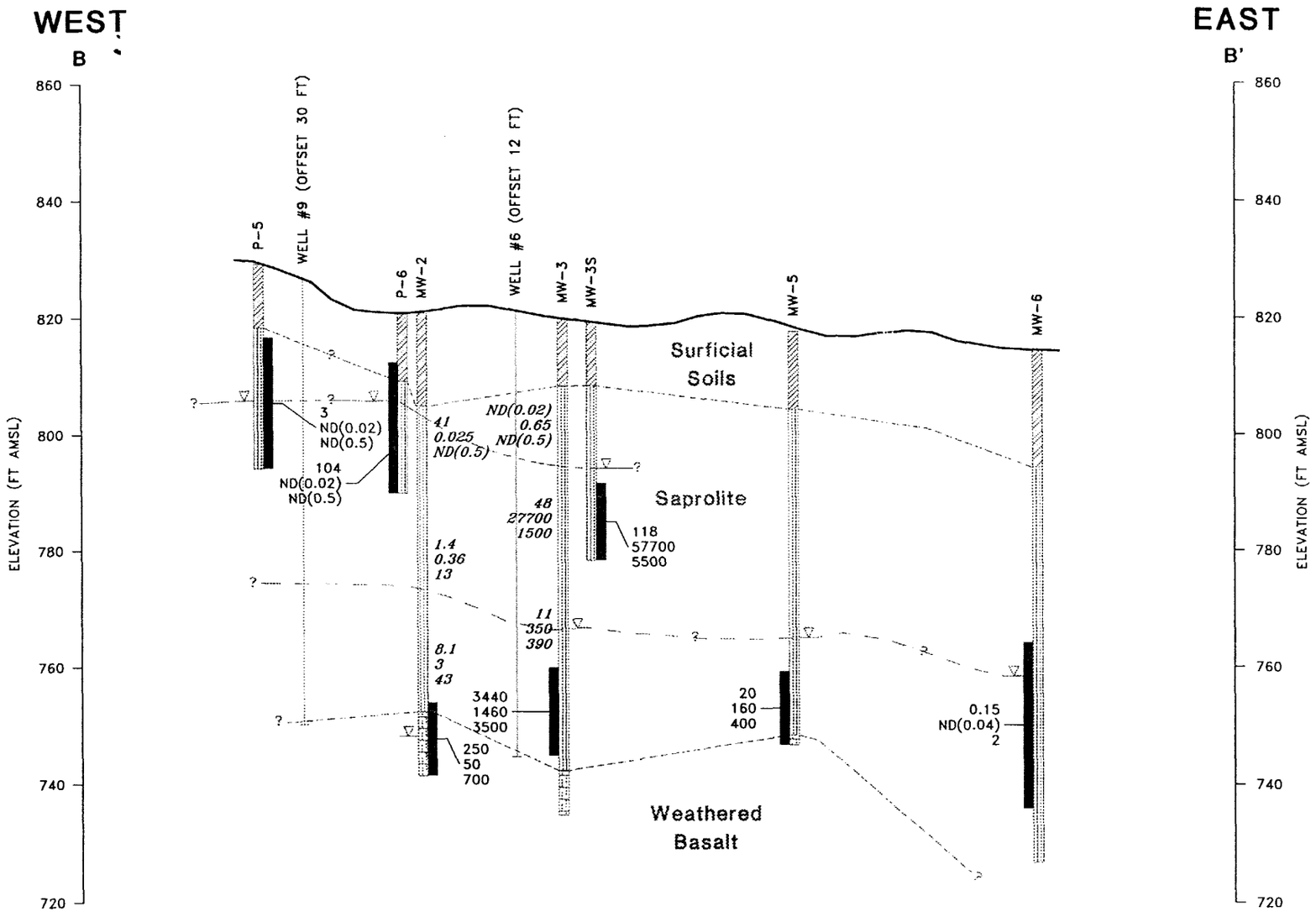
1. NO WELL WAS CONSTRUCTED AT AT MW-4. NO WATER WAS OBSERVED DURING DRILLING NOR ACCUMULATED IN THE OPEN BOREHOLE OVER A 24-HOUR PERIOD.
2. CROSS-SECTION LOCATIONS SHOWN IN FIGURE 3-15.
3. P-1 WATER LEVEL TAKEN IN SEPTEMBER 1997.
4. THE INDICATED EDB/DBCP/DCP CONCENTRATIONS ARE AVERAGES OF RESULTS SHOWN IN FIGURE 4-1.

0 60 120
FEET
VERTICAL 3X HORIZONTAL

FIGURE **4-2**

**VERTICAL DISTRIBUTION OF EDB/DBCP/DCP IN THE PERCHED AQUIFER CROSS-SECTION A-A'**

DEL MONTE/OAHU RI-FS/HI




EXPLANATION:

- 150 / 200 / 2 — SAND PACK INTERVAL WITH EDB, DBCP AND DCP CONCENTRATIONS (μg/L)
- 150 / 200 / 2 — HYDROPUNCH EDB, DBCP AND DCP RESULTS (μg/L)
- ND(0.5) — NOT DETECTED AT THE INDICATED CONCENTRATION
- GROUNDWATER ELEVATION (OCTOBER 1997)
- SOFT TO STIFF, GRAYISH BROWN (5YR 3/2) TO MODERATE BROWN (5YR 4/4), SILTY CLAY (SURFACE SOIL AND SUBSOIL)
- STIFF TO VERY STIFF, MODERATE BROWN TO GRAYISH RED, SILTY CLAY, FRIABLE, WITH MINERAL INFILLED VESICLES, OCCASIONAL WEATHERED BASALT BOULDERS (SAPROLITE)
- HARD, DARK GREENISH GRAY, WEATHERED BASALT
- POTENTIOMETRIC SURFACE OF THE UPPER PERCHED AQUIFER (OCTOBER 1997)
- POTENTIOMETRIC SURFACE OF THE LOWER PERCHED AQUIFER (OCTOBER 1997)
- GEOLOGIC CONTACT

NOTES:

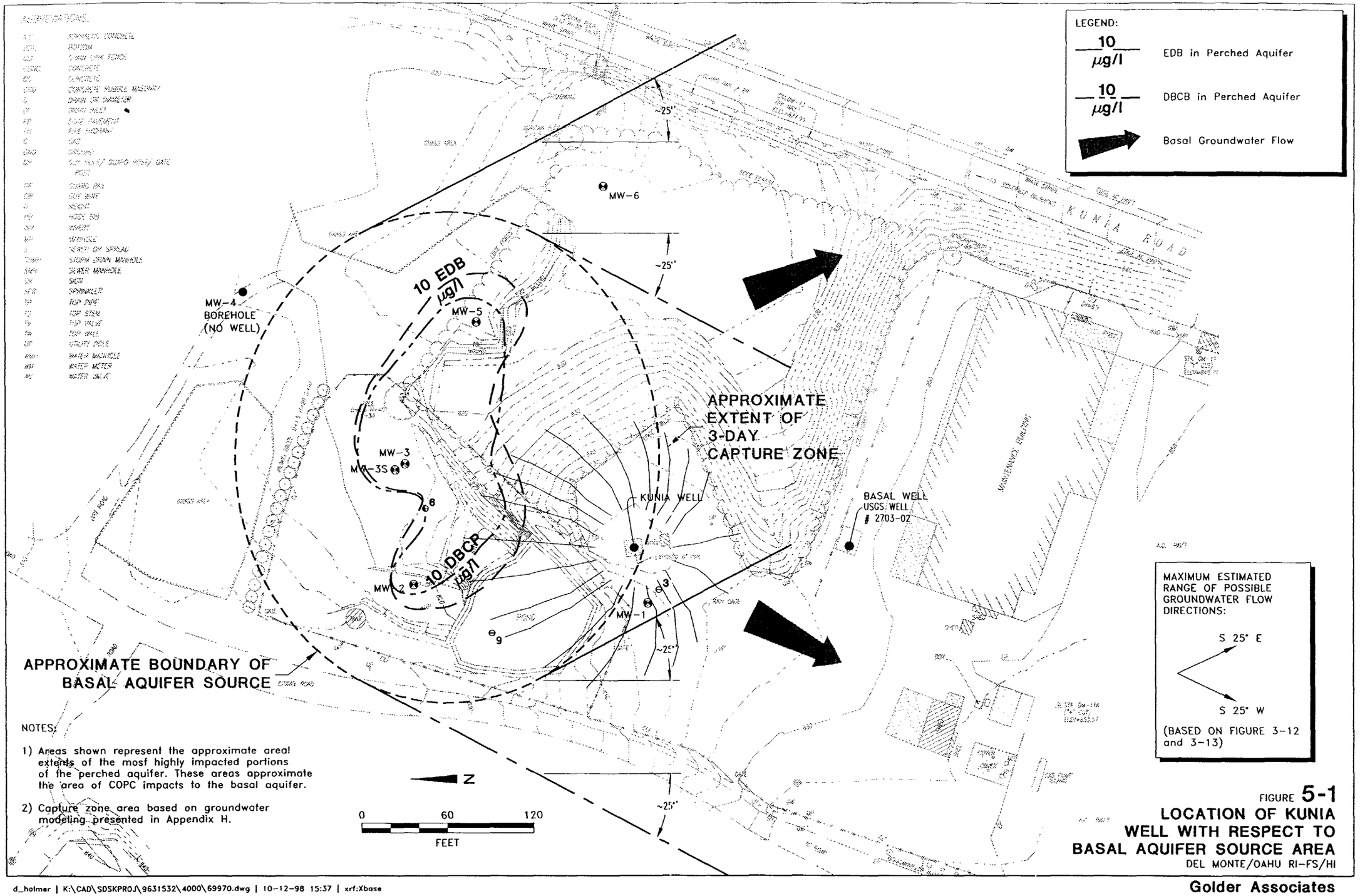
1. CROSS-SECTION LOCATIONS SHOWN IN FIGURE 3-15.
2. MW-2 WATER LEVEL MEASUREMENT NOT USED FOR POTENTIOMETRIC SURFACE SINCE WELL IS SCREENED PRIMARILY IN THE WEATHERED BASALT.
3. THE INDICATED EDB, DBCP AND DCP CONCENTRATIONS ARE AVERAGE VALUES OF RESULTS SHOWN IN FIGURE 4-1.

0 60 120
FEET
VERTICAL 3X HORIZONTAL

FIGURE **4-3**

**VERTICAL DISTRIBUTION OF EDB/DBCP/DCP IN THE PERCHED AQUIFER CROSS-SECTION B-B'**

DEL MONTE/OAHU RI-FS/HI




NOTES:

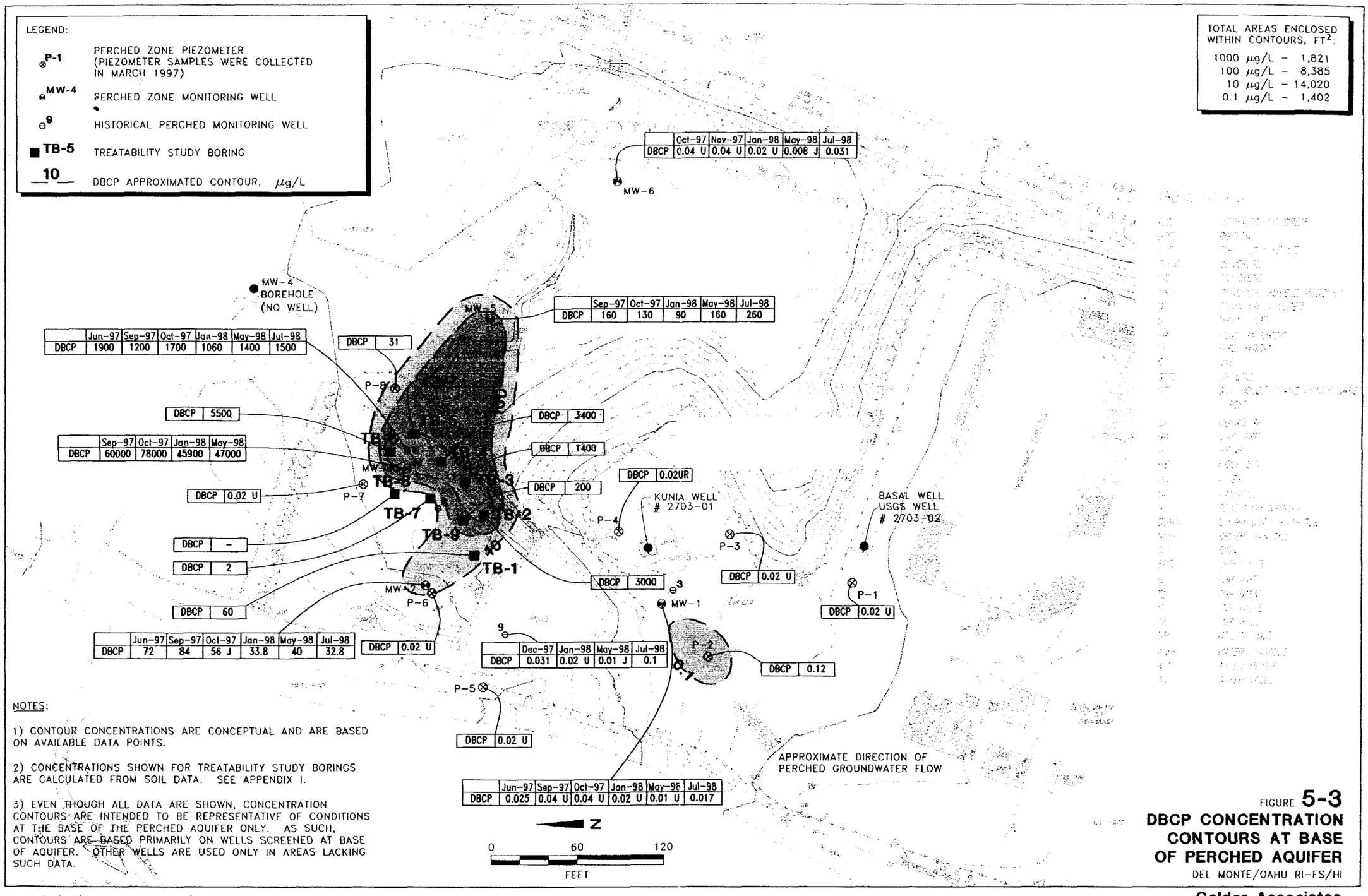
1) Areas shown represent the approximate areal extents of the most highly impacted portions of the perched aquifer. These areas approximate the area of COPC impacts to the basal aquifer.

2) Capture zone area based on groundwater modeling presented in Appendix H.

FIGURE 5-1
**LOCATION OF KUNIA WELL WITH RESPECT TO BASAL AQUIFER SOURCE AREA**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69970.dwg | 10-12-98 15:37 | xrf:Xbase

**Golder Associates**




NOTES:

1) CONTOUR CONCENTRATIONS ARE CONCEPTUAL AND ARE BASED ON AVAILABLE DATA POINTS.

2) CONCENTRATIONS SHOWN FOR TREATABILITY STUDY BORINGS ARE CALCULATED FROM SOIL DATA. SEE APPENDIX I.

3) EVEN THOUGH ALL DATA ARE SHOWN, CONCENTRATION CONTOURS ARE INTENDED TO BE REPRESENTATIVE OF CONDITIONS AT THE BASE OF THE PERCHED AQUIFER ONLY. AS SUCH, CONTOURS ARE BASED PRIMARILY ON WELLS SCREENED AT BASE OF AQUIFER. OTHER WELLS ARE USED ONLY IN AREAS LACKING SUCH DATA.

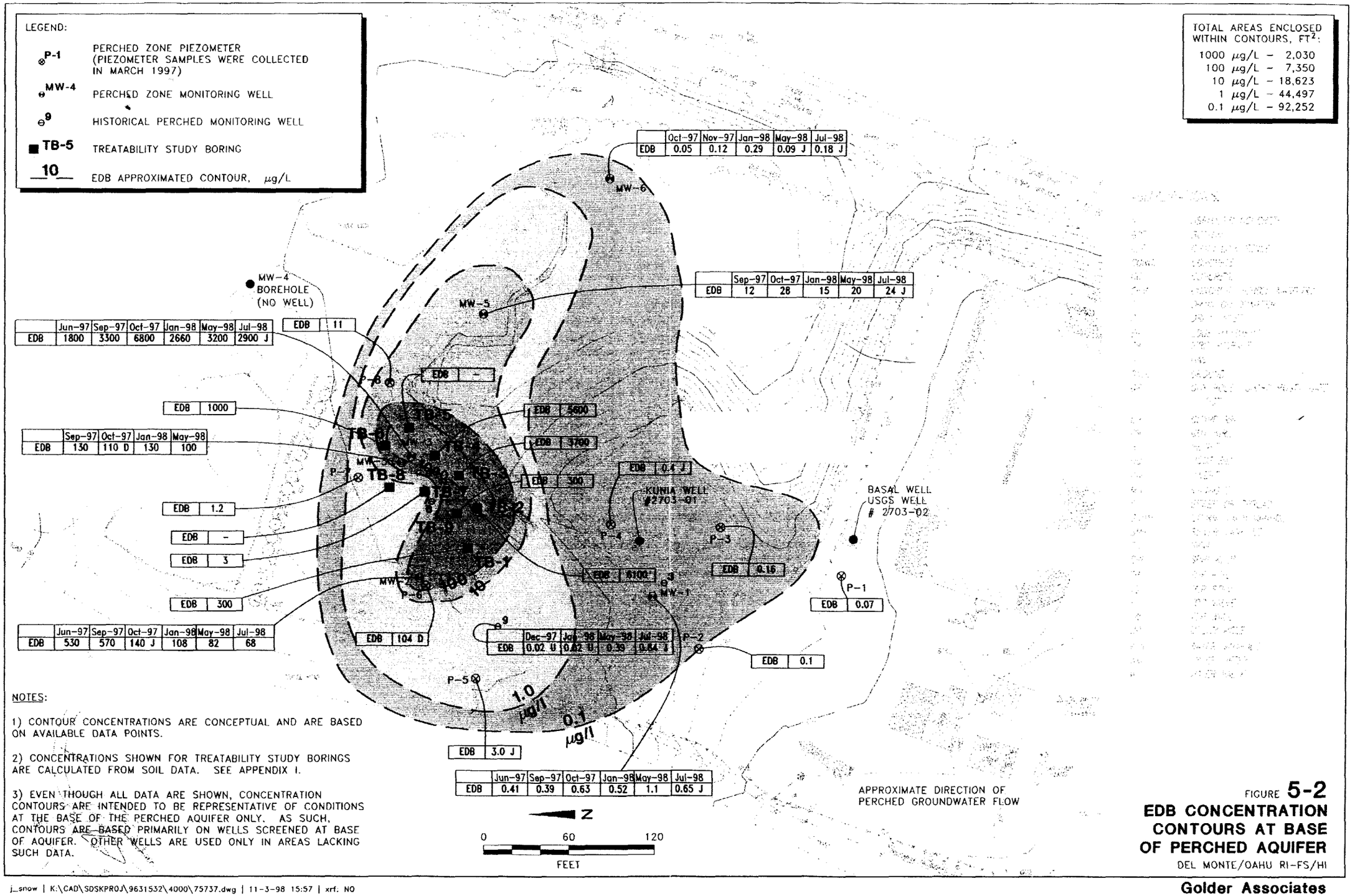
FIGURE **5-3**

**DBCP CONCENTRATION CONTOURS AT BASE OF PERCHED AQUIFER**

DEL MONTE/OAHU RI-FS/HI

j_snow | K:\CAD\SDSKPROJ\9631532\4000\75738.dwg | 11-3-98 15:09 | xrf: NO

**Golder Associates**




NOTES:

1) CONTOUR CONCENTRATIONS ARE CONCEPTUAL AND ARE BASED ON AVAILABLE DATA POINTS.

2) CONCENTRATIONS SHOWN FOR TREATABILITY STUDY BORINGS ARE CALCULATED FROM SOIL DATA. SEE APPENDIX I.

3) EVEN THOUGH ALL DATA ARE SHOWN, CONCENTRATION CONTOURS ARE INTENDED TO BE REPRESENTATIVE OF CONDITIONS AT THE BASE OF THE PERCHED AQUIFER ONLY. AS SUCH, CONTOURS ARE BASED PRIMARILY ON WELLS SCREENED AT BASE OF AQUIFER. OTHER WELLS ARE USED ONLY IN AREAS LACKING SUCH DATA.

FIGURE **5-2**

**EDB CONCENTRATION CONTOURS AT BASE OF PERCHED AQUIFER**

DEL MONTE/OAHU RI-FS/HI

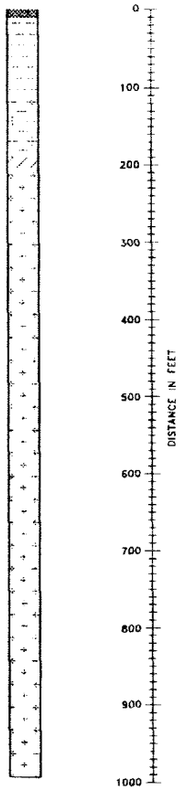
j_snow | K:\CAD\SDSKPROJ\9631532\4000\75737.dwg | 11-3-98 15:57 | xrf: NO

**Golder Associates**

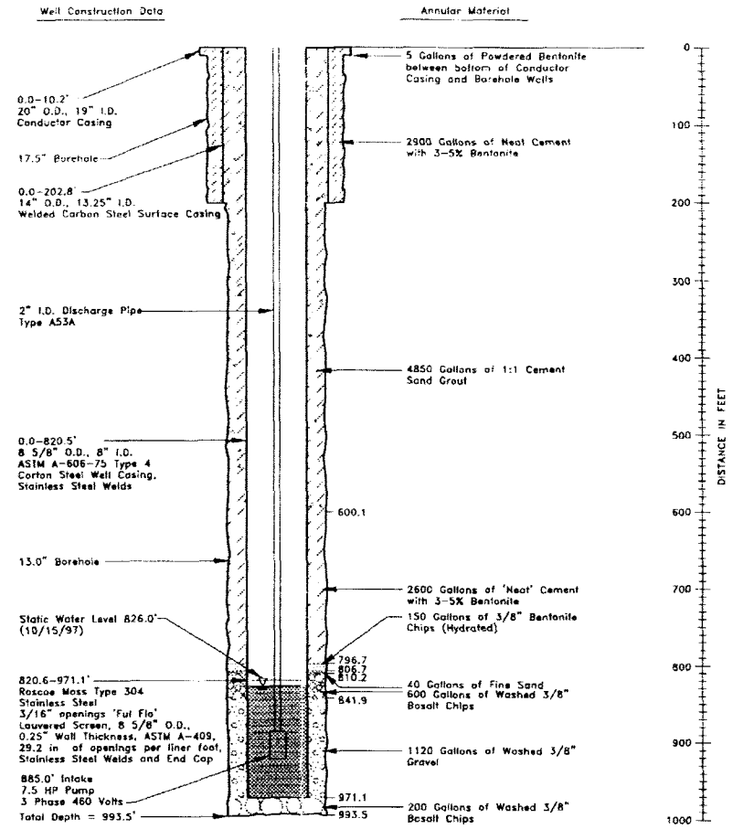
## STRATIGRAPHIC LOG (Based on cuttings curculated out of Borehole)

| | |
|---|---|
| 0.0–10.2' | No drilling, backfill area excavated |
| 10.2–115.0' | Stiff, dark reddish brown (10YR 3/4), CLAYEY SILT to SILTY CLAY, trace fine sand, (SAPROLITE), (CL) |
| 115.0–190.0' | Stiff, moderate olive brown (5Y 4/4) and dark reddish brown (10YR 3/4), SILTY CLAY/ CLAYEY SILT to weathered BASALT, (Transition between SAPROLITE and BASALT) |
| 190.0–202.8' | Light olive gray (5Y 5/6), weak, BASALT, (transition from weathered BASALT to BASALT) |
| 202.8–210.0' | See Description 3 |
| 210.0–215.0' | See Description 3 |
| 215.0–230.0' | See Description 1 |
| 230.0–245.0' | See Description 5 |
| 245.0–250.0' | See Description 1 |
| 257.0–315.0' | See Description 4 |
| 315.0–332.0' | See Description 2 |
| 332.0–341.0' | See Description 4 |
| 341.0–353.0' | See Description 5 |
| 353.0–365.0' | See Description 2 |
| 365.0–380.0' | See Description 5 |
| 380.0–387.5' | See Description 2 |
| 387.5–405.0' | See Description 3 |
| 405.0–415.0' | See Description 2 |
| 415.0–430.0' | See Description 5 |
| 430.0–440.0' | See Description 2 |
| 440.0–450.0' | See Description 3 |
| 450.0–460.0' | See Description 2 |
| 460.0–465.0' | See Description 3 |
| 465.0–485.0' | See Description 2 |
| 485.0–520.0' | See Description 3 |
| 520.0–534.0' | See Description 2 |
| 534.0–545.0' | See Description 1 |
| 545.0–595.0' | See Description 2 |
| 595.0–610.0' | See Description 1 |
| 610.0–615.0' | See Description 2 |
| 615.0–620.0' | See Description 1 |
| 620.0–658.0' | See Description 2 |
| 658.0–668.0' | See Description 1 |
| 668.0–702.5' | See Description 2 |
| 702.5–725.0' | See Description 1 |
| 725.0–993.5' | See Description 2 |

Note: Start to observe 'soft' moderate reddish brown (10R 4/6) cuttings at 885.0' with the BASALT that can be easily etched with fingernail – possibly SAPROLITE.

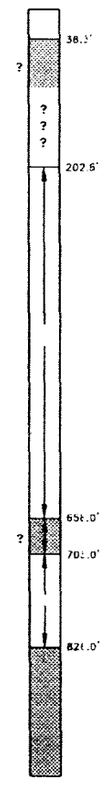



## USGS WELL 27032




NOTE: ALL DEPTHS ARE REFERENCED TO GROUND SURFACE.

## WATER NOTES WHILE DRILLING




Perched Water

Water level measured at 38.3' BGS after borehole idle for more than 12 hours while drilling down to 202.8'. No water detected after casing grouted and drilling resumed at 202.8' BGS. Caution should be taken in interpreting water level data in open boreholes. The bottom of the saturated zone is uncertain but does not extend below 202.8' BGS.

202.8–658.0' No water detected while drilling, based on dry foam circulated out of borehole, measurements with an electric tape in the mornings prior to drilling, and lack of water return when borehole cleaned out with air prior to drilling in morning

658.0–705.0' Driller noted some water in hole based on wetness detected in foam circulated out of borehole

705.0–826.0' No water detected while drilling (see notes 202.8' to 658.0')

826.0–993.5' Basal Aquifer

## DESCRIPTION OF BASALT CUTTINGS

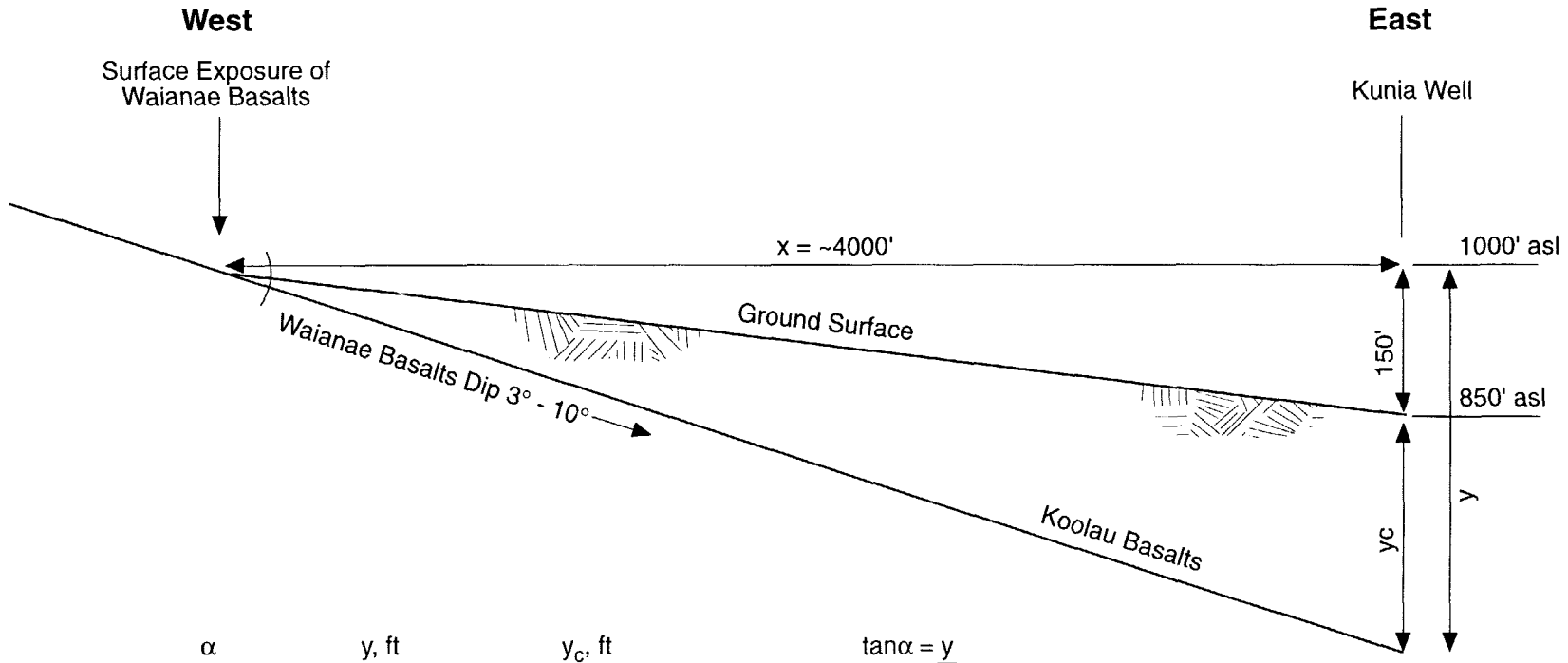
1. Moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4), BASALT
2. Moderate reddish brown (10R 4/6) to greenish black (5GY 2/1), BASALT
3. Greenish black (5GY 2/1), BASALT
4. Very dusky red (10R 2/2) to greenish black (5GY 2/1), BASALT
5. Grayish olive (10Y 4/2), BASALT

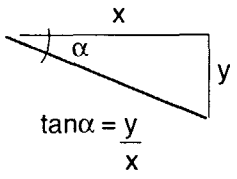
Note: Drilling penetration rate generally increases in reddish colored BASALT.

FIGURE **3-20**

**BASAL WELL BORING LOG AND WELL CONSTRUCTION DIAGRAM**

DEL MONTE/OAHU RI-FS/HI




$\tan\alpha = \frac{y}{x}$

| $\alpha$ | y, ft | $y_c$, ft |
|---|---|---|
| 3° | 210 | 60 |
| 5° | 350 | 200 |
| 8° | 562 | 412 |
| 10° | 705 | 555 |

← DTW=~825

$\tan\alpha = \frac{y}{x}$

$y = \tan\alpha \bullet 4000$

$y_c = y - 150'$ = Depth to Contact from Ground Surface

$\therefore y_c = \tan\alpha \bullet 4000 - 150'$

CONCLUSION

This calculation suggests the depth to the top of the Waianae basalts is less than about 550'. Since the depth to water in the Kunia Well is approximately 300' deeper than this, the well is believed constructed in the Waianae.

DTW - Depth to Water Table

asl - Above Sea Level

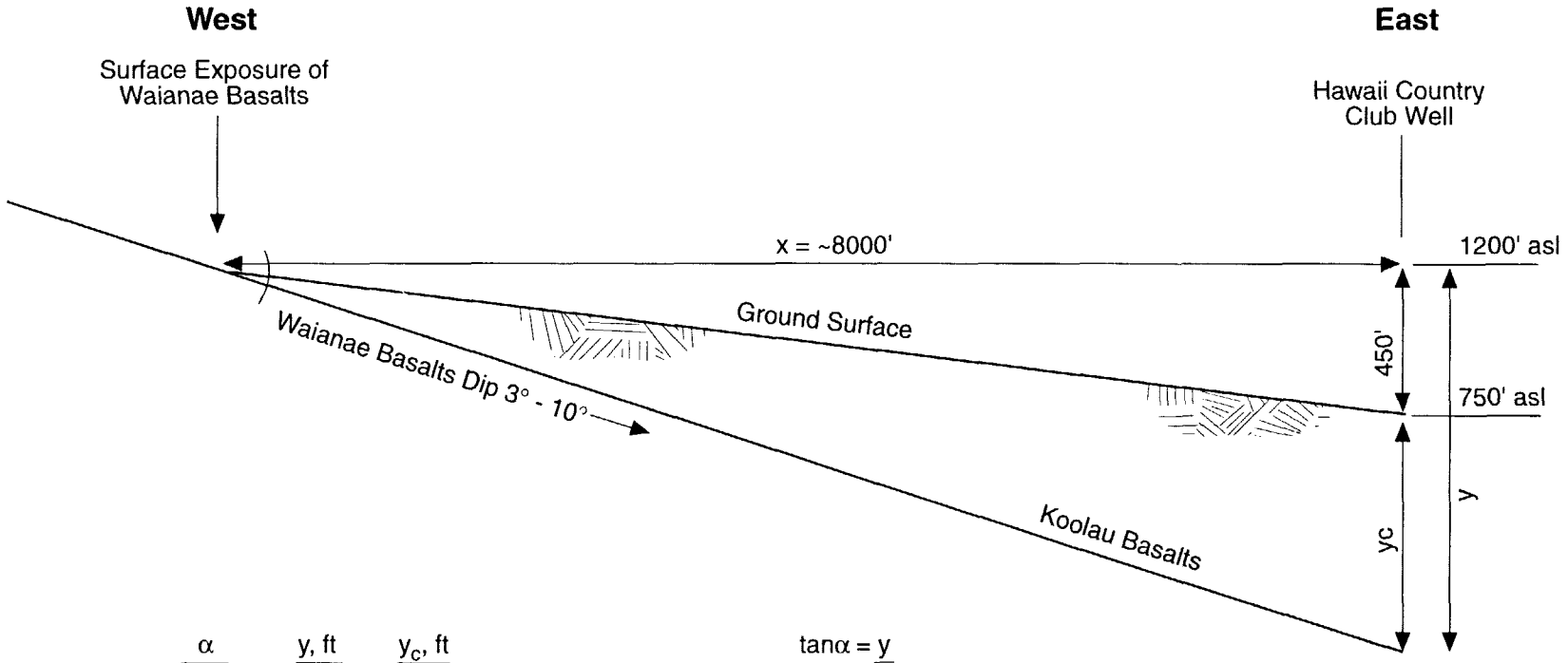
FIGURE **3-21**

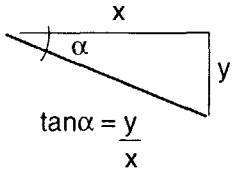
**CALCULATION OF THE DEPTH TO WAIANAE BASALTS AT THE KUNIA VILLAGE AREA**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 77008 DATE 3/23/98 DRAWN BY EA

**Golder Associates**




| α | y, ft | $y_c$, ft |
|---|---|---|
| 3° | 420 | 0 |
| 5° | 700 | 250 |
| 8° | 1120 | 670 ← DTW = ~720 |
| 10° | 1410 | 960 |

$\tan\alpha = \frac{y}{x}$

$y = \tan\alpha \bullet 8000$

$y_c = y - 450'$

$\therefore y_c = \tan\alpha \bullet 8000 - 450'$

CONCLUSION

This calculation suggests the depth to the top of the Waianae basalts is less than about 960'. Since the depth to water in the Country Club Well is approximately 720' bgs, it is possible the well is completed in the Koolau basalts, or the Waianae basalts.

DTW - Depth to Water at Country Club Well

asl - above sea level

FIGURE **3-22**

**CALCULATION OF THE DEPTH TO WAIANAE BASALTS AT THE HAWAII COUNTRY CLUB WELL**

DEL MONTE/OAHU RI-FS/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 77009 DATE 5/5/98 DRAWN BY EA

**Golder Associates**

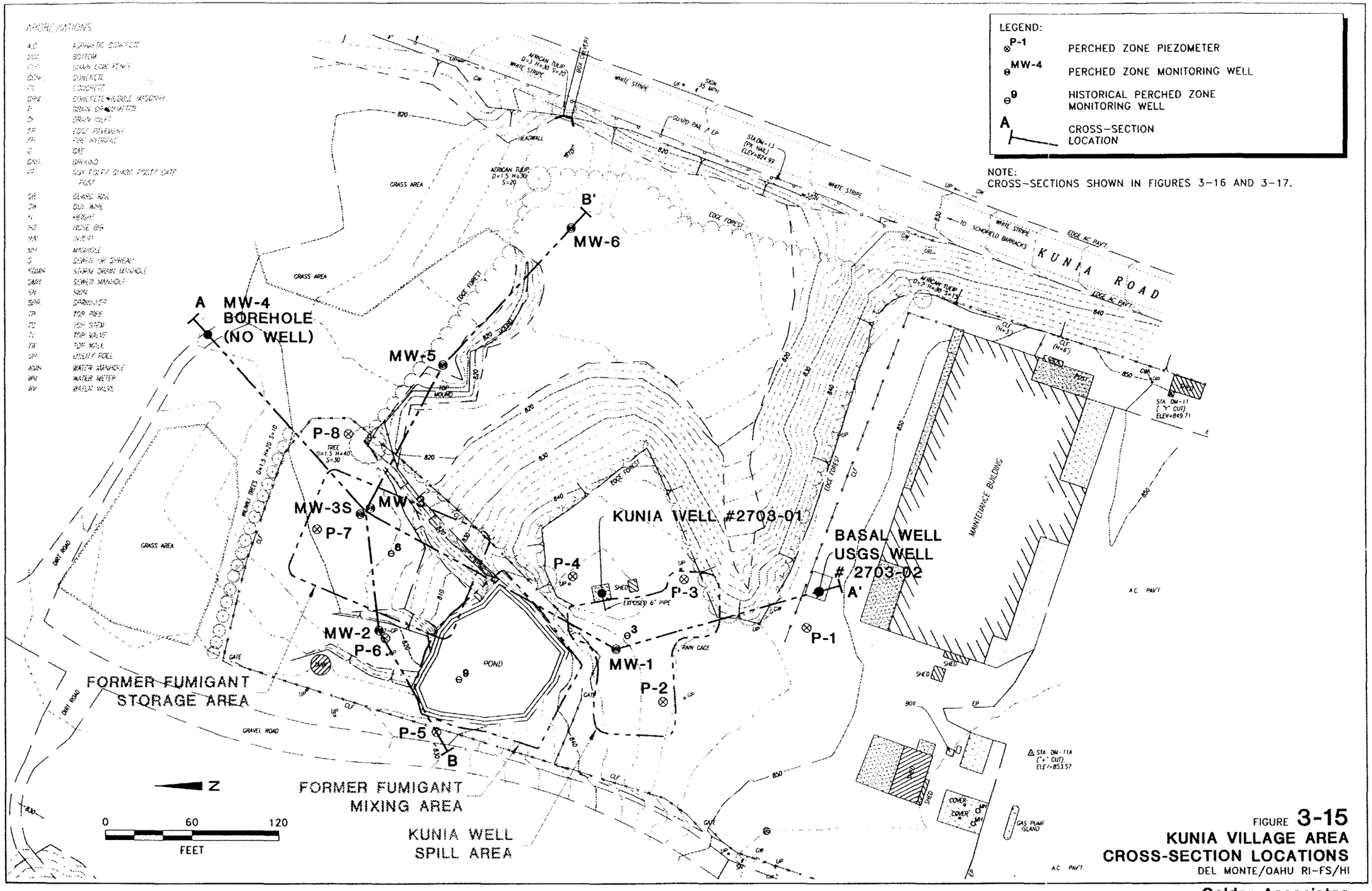
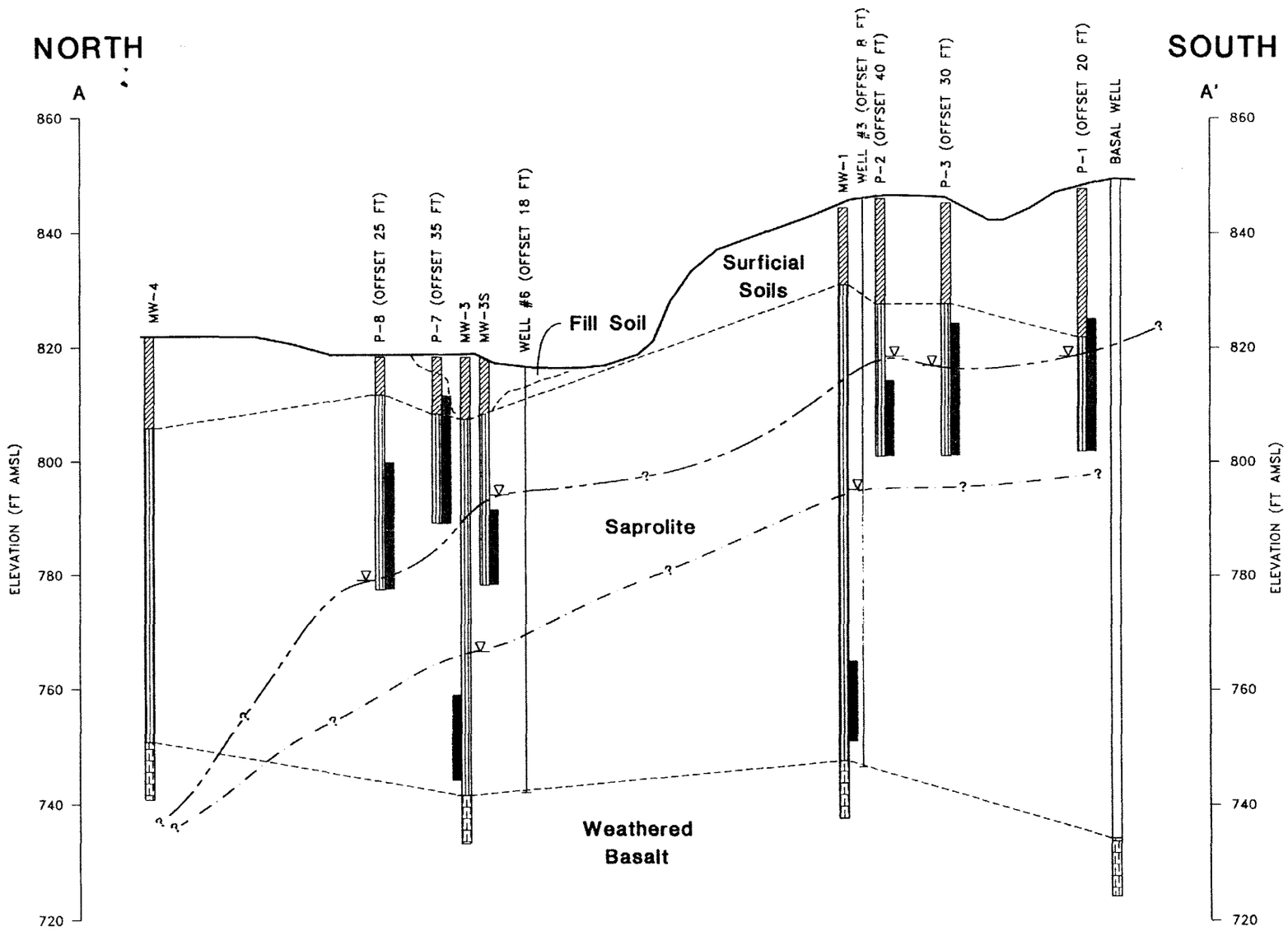



FIGURE 3-15
KUNIA VILLAGE AREA
CROSS-SECTION LOCATIONS
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\75601.dwg | 10-9-98 16:08 | xrf:Xbase

Golder Associates




EXPLANATION:

- SAND PACK INTERVAL
- GROUNDWATER ELEVATION (OCTOBER 1997)
- SOFT TO STIFF, GRAYISH BROWN (5YR 3/2) TO MODERATE BROWN (5YR 4/4), SILTY CLAY (SURFACE SOIL AND SUBSOIL)
- STIFF TO VERY STIFF, MODERATE BROWN TO GRAYISH RED, SILTY CLAY, FRIABLE, WITH MINERAL INFILLED VESICLES, OCCASIONAL WEATHERED BASALT BOULDERS (SAPROLITE)
- HARD, DARK GREENISH GRAY, WEATHERED BASALT
- POTENTIOMETRIC SURFACE OF THE UPPER PERCHED AQUIFER
- POTENTIOMETRIC SURFACE OF THE LOWER PERCHED AQUIFER
- GEOLOGIC CONTACT

NOTES:

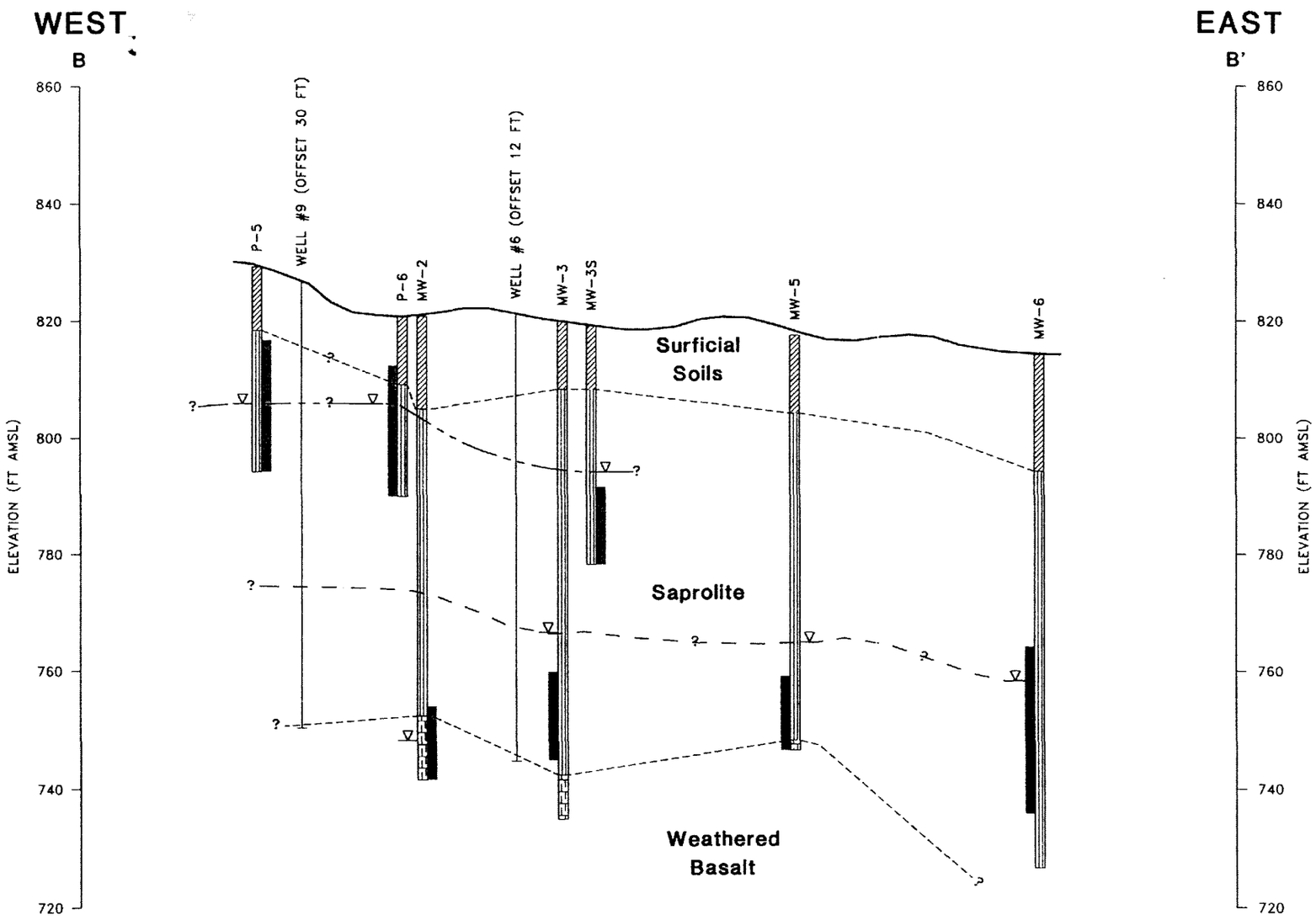
1. NO WELL WAS CONSTRUCTED AT AT MW-4. NO WATER WAS OBSERVED DURING DRILLING NOR ACCUMULATED IN THE OPEN BOREHOLE OVER A 24-HOUR PERIOD.
2. CROSS-SECTION LOCATIONS SHOWN IN FIGURE 3-15.
3. P-1 WATER LEVEL TAKEN IN SEPTEMBER 1997.
4. NO GEOLOGIC DATA ARE AVAILABLE FOR WELLS #3 AND #6, AND THESE BORINGS WERE NOT USED TO GENERATE THIS CROSS-SECTION. ONLY THE REPORTED DEPTHS OF THE BORINGS ARE INDICATED.
5. A PORTION OF WELL #6 WAS CUT OFF DURING PREVIOUS REMEDIAL ACTIVITIES. THE LENGTH OF WELL REMOVED WAS NOT DOCUMENTED. THE ELEVATION OF THE WELL SHOWN HERE IS BASED ON AN ASSUMED REMOVAL OF ABOUT 4 FEET.

0 60 120
FEET
VERTICAL 3X HORIZONTAL

FIGURE **3-16**
**KUNIA VILLAGE AREA CROSS-SECTION A-A'**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69933.dwg | 10-14-98 9:49 | xrf: NO

**Golder Associates**




EXPLANATION:

- SAND PACK INTERVAL
- GROUNDWATER ELEVATION (OCTOBER 1997)
- SOFT TO STIFF, GRAYISH BROWN (5YR 3/2) TO MODERATE BROWN (5YR 4/4), SILTY CLAY (SURFACE SOIL AND SUBSOIL)
- STIFF TO VERY STIFF, MODERATE BROWN TO GRAYISH RED, SILTY CLAY, FRIABLE, WITH MINERAL INFILLED VESICLES, OCCASIONAL WEATHERED BASALT BOULDERS (SAPROLITE)
- HARD, DARK GREENISH GRAY, WEATHERED BASALT
- POTENTIOMETRIC SURFACE OF THE UPPER PERCHED AQUIFER
- POTENTIOMETRIC SURFACE OF THE LOWER PERCHED AQUIFER
- GEOLOGIC CONTACT

NOTES:

1. CROSS-SECTION LOCATIONS SHOWN IN FIGURE 3-15.
2. MW-2 WATER LEVEL MEASUREMENT NOT USED FOR POTENTIOMETRIC SURFACE SINCE WELL IS SCREENED PRIMARILY IN THE WEATHERED BASALT.
3. NO GEOLOGIC DATA ARE AVAILABLE FOR WELLS #6 AND #9, AND THESE BORINGS WERE NOT USED TO GENERATE THIS CROSS-SECTION. ONLY THE REPORTED DEPTHS OF THE BORINGS ARE INDICATED.
4. PORTIONS OF WELLS #6 AND #9 WERE CUT OFF AS PART OF PREVIOUS REMEDIAL ACTIVITIES. THE LENGTH OF EACH WELL CUT OFF HAS NOT BEEN DOCUMENTED. THE ELEVATIONS SHOWN HERE ARE BASED ON AN ASSUMED REMOVAL OF ABOUT 4 FT FOR WELL #6 AND 10 FT FOR WELL #9.

0 60 120
FEET
VERTICAL 3X HORIZONTAL

FIGURE **3-17**
**KUNIA VILLAGE AREA CROSS-SECTION B-B'**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69934.dwg | 10-9-98 16:39 | xrf: NO

**Golder Associates**

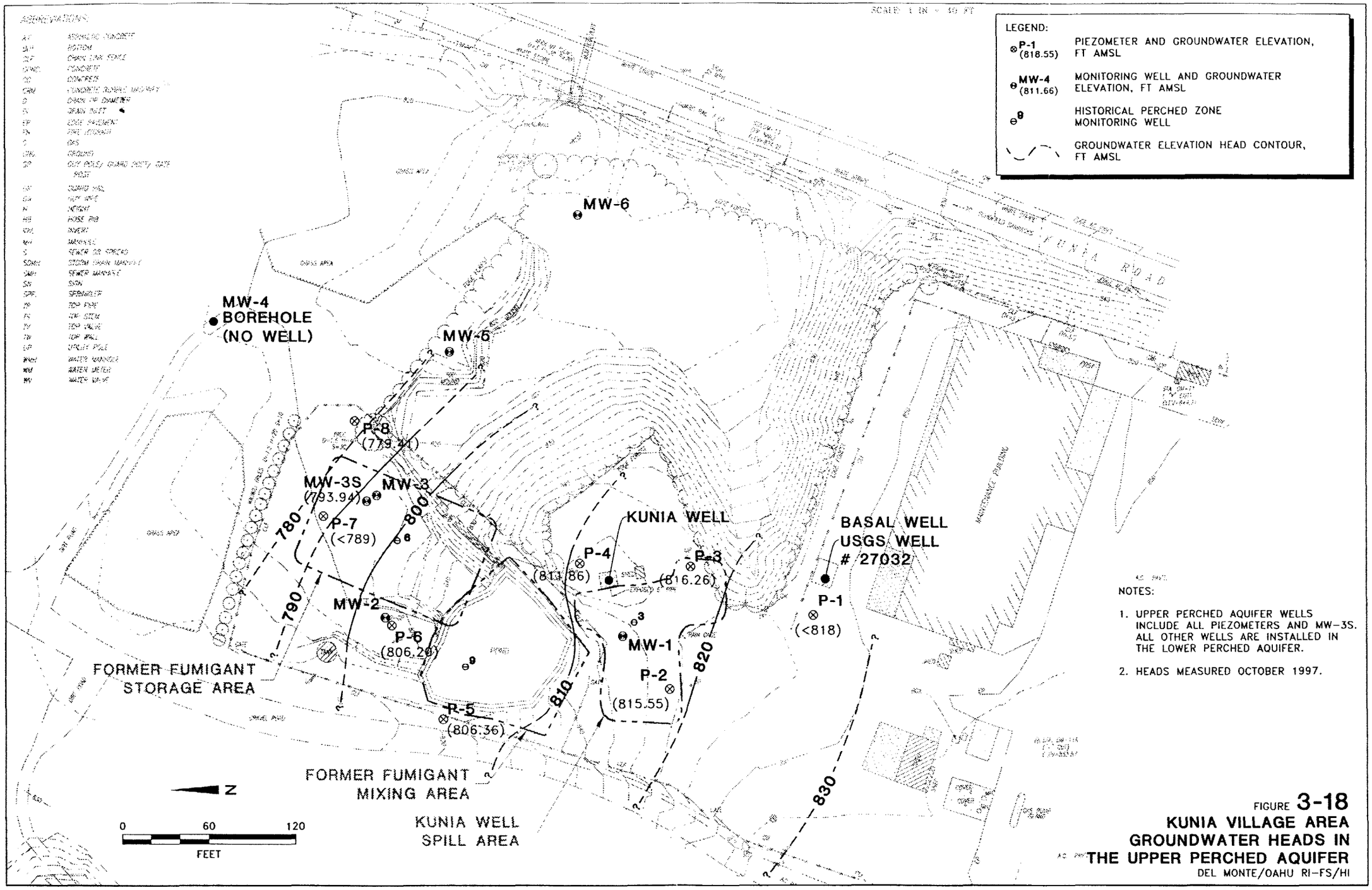



FIGURE 3-18
**KUNIA VILLAGE AREA GROUNDWATER HEADS IN THE UPPER PERCHED AQUIFER**
DEL MONTE/OAHU RI-FS/HI

d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69931.dwg | 10-12-98 10:01 | xrf:Xbase

**Golder Associates**

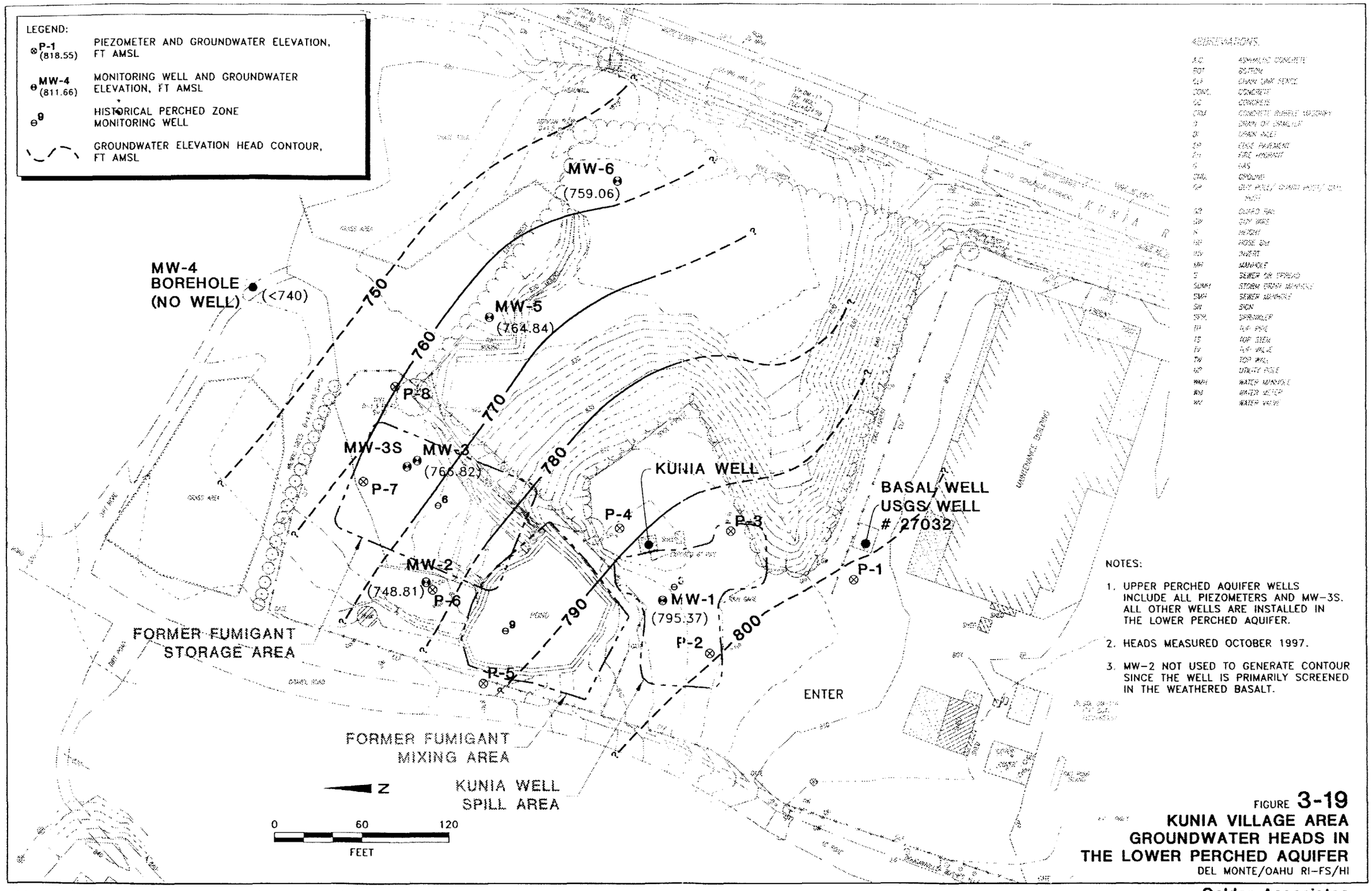
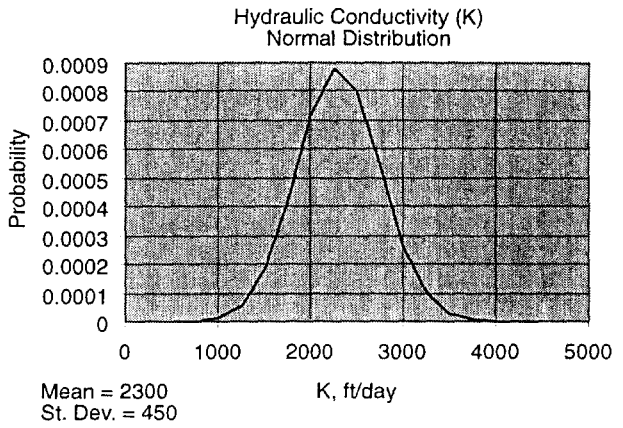


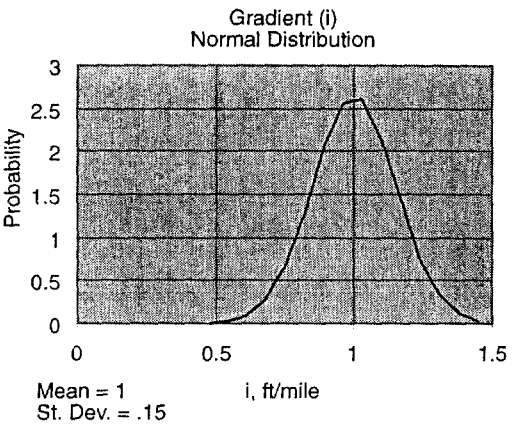

FIGURE 3-19
**KUNIA VILLAGE AREA GROUNDWATER HEADS IN THE LOWER PERCHED AQUIFER**
DEL MONTE/OAHU RI-FS/HI

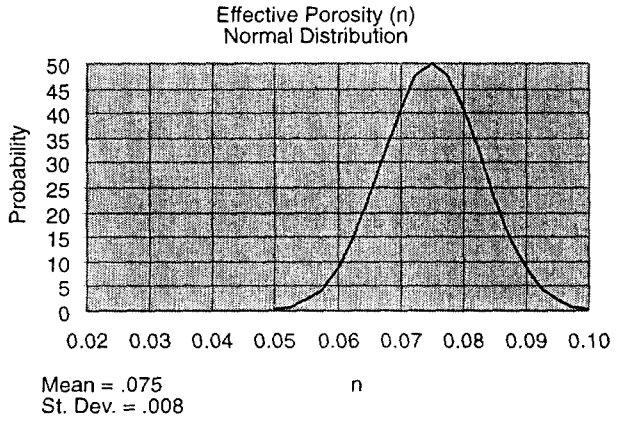
d_holmer | K:\CAD\SDSKPROJ\9631532\4000\69932.DWG | 10-13-98 13:30 | xrf:Xbase

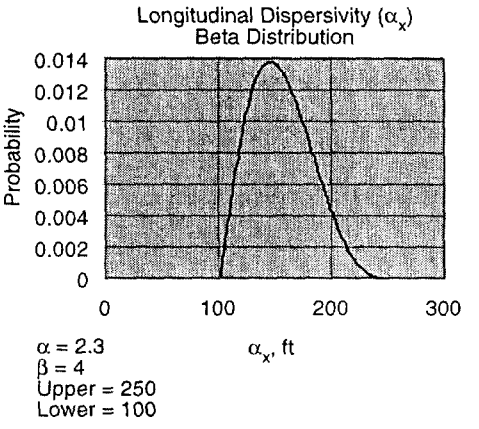
**Golder Associates**

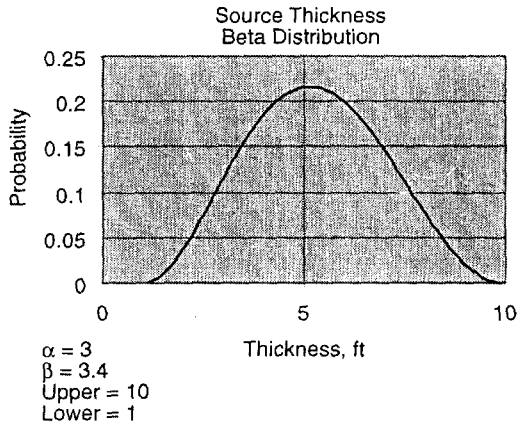
DRAWING

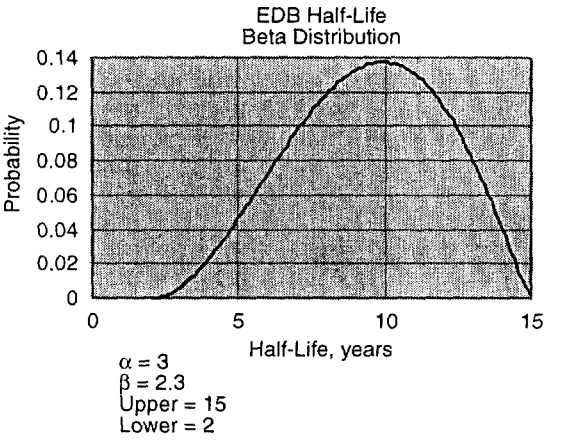


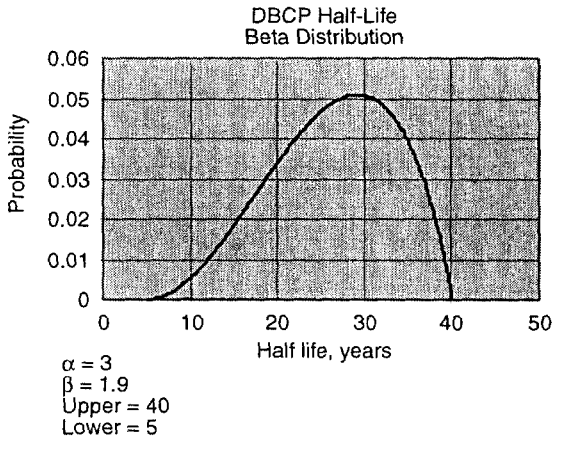



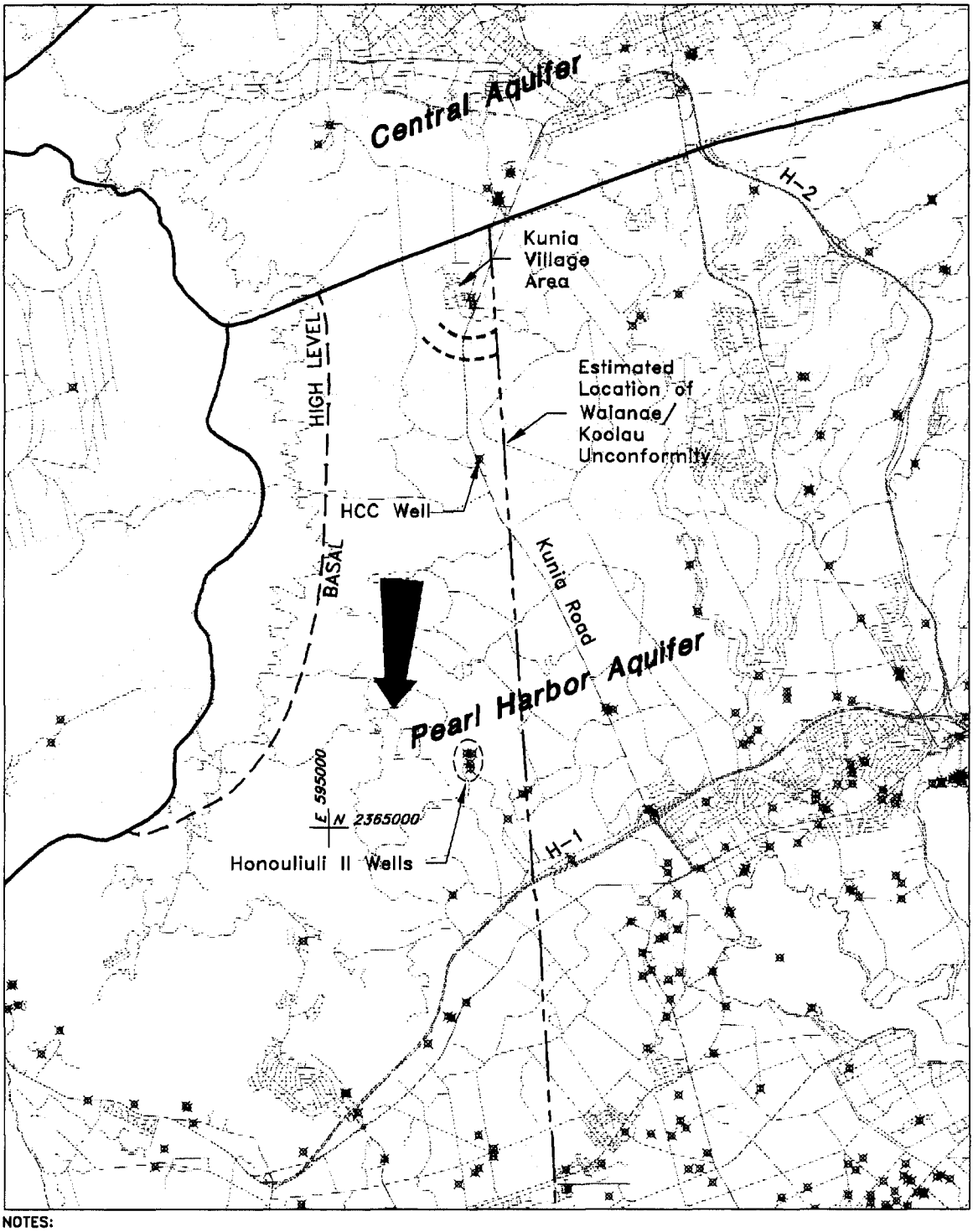

FIGURE **5-4**

**BASAL AQUIFER TRANSPORT PARAMETERS (PDFs) USED IN BIOSCREEN MODELING**

DEL MONTE/OAHU PLANTATION/HI

PROJECT NO. 963 1532.4000 DRAWING NO. 77142 DATE 3/10/98 DRAWN BY EA

**Golder Associates**




NOTES:
1) SEE FIGURE 3-14 FOR WELL NAMES AND STATE WELL NUMBERS OF SELECTED KEY WELLS.
2) NOT ALL WELLS SHOWN ARE CURRENTLY ACTIVE.
3) SOURCE: BASE MAP MODIFIED FROM MINK AND LAU (1990) AND HDOH (1996).
4) TRAVEL DISTANCES FOR DCP & TCP ARE BOTH <100 FT AND ARE NOT SHOWN.

LEGEND:

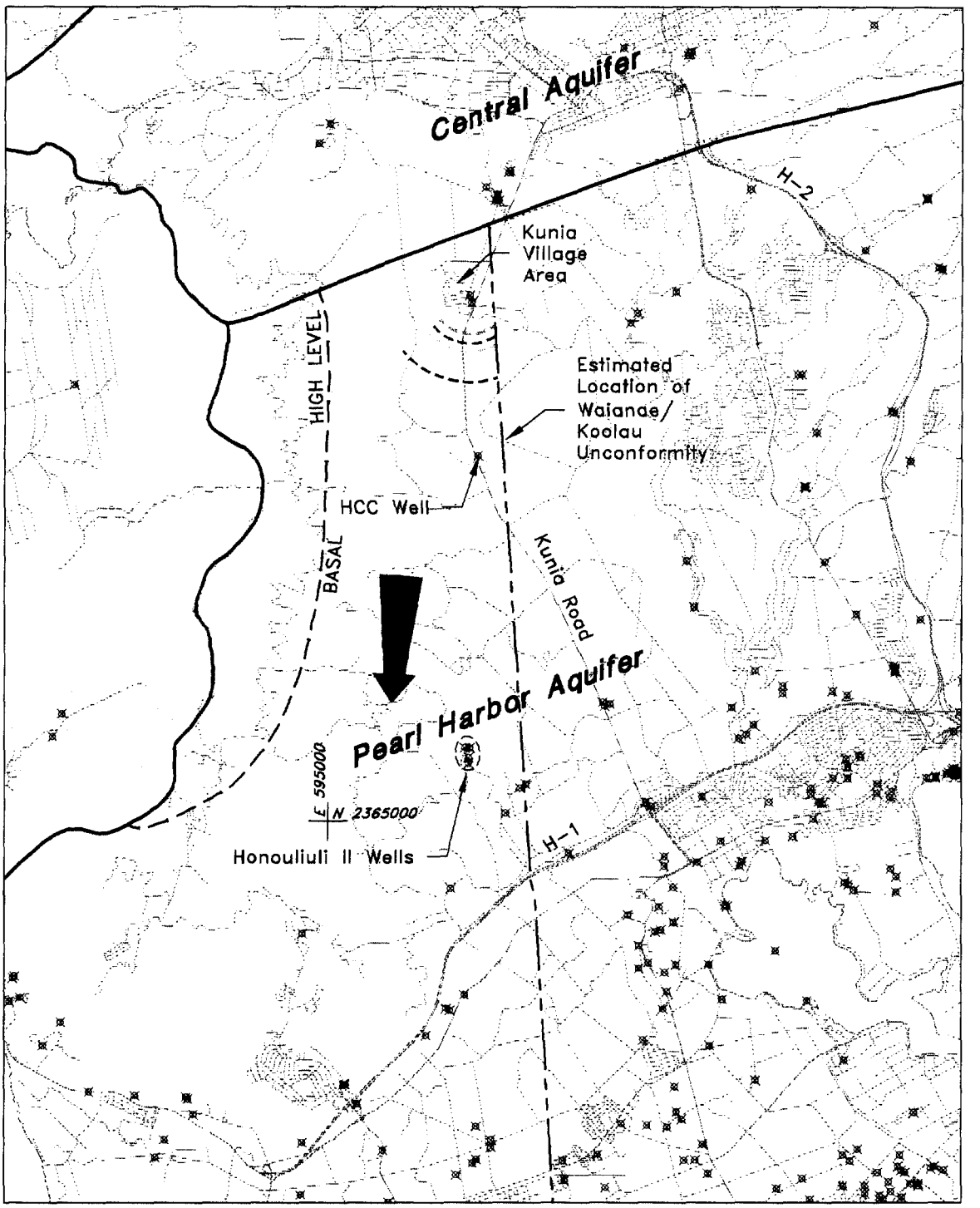
- 90TH PERCENTILE TRAVEL DISTANCE TO MCL (EDB)
- 90TH PERCENTILE TRAVEL DISTANCE TO MCL (DBCP)
- AQUIFER SECTOR BOUNDARY
- *Central* AQUIFER SECTOR NAME
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- WELL LOCATION

0 3000 6000 METERS
0 10000 20000 FEET

FIGURE **5-5**

**FUTURE TRAVEL DISTANCES FOR EXISTING (1997) EDB/DBCP (ASSUMING NO SOURCE DECAY)**

DEL MONTE/OAHU/HI




NOTES:
1) SEE FIGURE 3-14 FOR WELL NAMES AND STATE WELL NUMBERS OF SELECTED KEY WELLS.
2) NOT ALL WELLS SHOWN ARE CURRENTLY ACTIVE.
3) SOURCE: BASE MAP MODIFIED FROM MINK AND LAU (1990) AND HDOH (1996).

LEGEND:

| | | |
|---|---|---|
| BEST | 1800' | REASONABLE BEST, AVERAGE AND |
| AVERAGE | --2500'-- | REASONABLE WORST CASE 17 YEAR |
| WORST | --4500'-- | (1998) EDB TRAVEL DISTANCES TO MCL |
| BEST | 2000' | REASONABLE BEST, AVERAGE AND |
| AVERAGE | 2900' | REASONABLE WORST CASE 17 YEAR |
| WORST | --4500'-- | (1998) DBCP TRAVEL DISTANCES TO MCL |

AQUIFER SECTOR BOUNDARY

*Central* AQUIFER SECTOR NAME

APPROXIMATE GROUNDWATER FLOW DIRECTION

WELL LOCATION

0 3000 6000 METERS

0 10000 20000 FEET

FIGURE **5-6**

**CURRENT TRAVEL DISTANCES FOR PRIOR (1980-1998) EDB/DBCP (WITH SOURCE DECAY)**

DEL MONTE/OAHU/HI

PARTIALLY SCANNED
OVERSIZE ITEM (S)

See Document # 136629
for partially scanned image(s).

For complete version of oversize document(s),
see paper copy.

OVD-parent