Public Health Assessment for

PEARL HARBOR NAVAL COMPLEX
PEARL HARBOR, HAWAII
EPA FACILITY ID: HI4170090076
DECEMBER 28, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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PUBLIC HEALTH ASSESSMENT

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Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services

Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, is an agency of the U.S. Public Health Service. Congress established this agency in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste areas. The U.S. Environmental Protection Agency (EPA) and the individual states regulate the investigation and cleanup of the areas.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the areas on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. (The legal definition of a health assessment is included on the inside front cover.) If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at an area, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data. Instead, it reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data are needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists then evaluate whether or not there will be any harmful effects from these exposures. The report focuses on public health, or the health impact on the community as a whole, rather than on individual risks. Again, ATSDR generally makes use of existing scientific information, which can include the results of medical, toxicologic, and epidemiologic studies and the data collected in disease registries. The science of environmental health is still developing, and occasionally scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further research studies are needed.

Conclusions: The report presents conclusions about the level of health threat, if any, posed by an area. In its public health action plan, the report recommends ways to stop or reduce exposure. ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory to warn people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies, or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the area and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near an area, including residents of the area, civic leaders, health professionals, and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for comment. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

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List of Abbreviations

AST	above-ground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	benzene, toluene, ethylbenzene, and xylenes
CEL	cancer effect level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CREG	cancer risk evaluation guide (ATSDR)
CSF	cancer slope factor
CV	comparison value
DCE	dichloroethylene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DHHS	U.S. Department of Health and Human Services
EJFDF	Ewa Junction Fuel Drumming Facility
EMEG	environmental media evaluation guide (ATSDR)
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
FDA	U.S. Food and Drug Administration
FFA	Federal Facility Agreement
FISC	Fleet and Industrial Supply Center, Pearl Harbor
GSA	geographic study area
HDOH	Hawaii Department of Health
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effect level
mg	milligram
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
MCPP	2-(2-methyl-4-chlorophenoxy) propionic acid
MOGAS	motor gasoline
MRL	minimal risk level (ATSDR)
µg	microgram
NA	not available
NAVFAC HI	Naval Facilities Engineering Command Hawaii – formerly PWC
NAVMAG PH	Naval Magazine Pearl Harbor – formerly Naval Magazine Lualualei
NAVSHIPYD& IMF	Naval Shipyard and Intermediate Maintenance Facility – formerly NAVSHPYD
NAVSTA	Naval Station, Pearl Harbor
NISMO	Naval Sea Systems Command, Inactive Ship On-Site Maintenance Office
NOAEL	no-observed-adverse-effect level
NPL	National Priorities List
OWDF	oily waste disposal facility
PAH	polycyclic aromatic hydrocarbon

List of Abbreviations

PCB	polychlorinated biphenyl
PCE	tetrachloroethylene, also known as perchloroethylene
PCPLF	Pearl City Peninsula Landfill
PHA	public health assessment
PHNC	Pearl Harbor Naval Complex
ppm	parts per million
ppmv	parts per million by volume
PWC	Navy Public Works Center, Pearl Harbor
RBC	risk-based concentration (EPA)
RCRA	Resource Conservation and Recovery Act
RfD	reference dose (EPA)
RI	Remedial Investigation
RMEG	reference media evaluation guide (ATSDR)
SARA	Superfund Amendment and Reauthorization Act
SSL	soil screening level
SSR	site summary report
SUBASE	Naval Submarine Base, Pearl Harbor
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCE	trichloroethylene
TEF	toxic equivalency factor
TEQ	toxic equivalent
TNT	2,4,6-trinitrotoluene
TPH	total petroleum hydrocarbons
UIC	underground-injection control
UST	underground storage tank
VOC	volatile organic compound
WALF	Waipahu Ash Landfill

Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted a public health assessment (PHA) of the Pearl Harbor Naval Complex (PHNC). As a part of the assessment process, ATSDR toured the base and met with base and community representatives. ATSDR also reviewed environmental information describing the investigations, sampling results, and remediation actions performed at PHNC. The purpose of the assessment was to identify if community members could come into contact with PHNC-related environmental contaminants and evaluate whether that contact could cause adverse health effects.

PHNC is an active Naval installation with an operational history extending back to 1899. Many on-base sites have been contaminated as a result of past chemical spills and material disposal practices. Numerous remedial investigations have taken place throughout PHNC, and many are still in process. By June 2002, the Navy had evaluated 5,197 sites, of which 4,448 were determined to require no further action because the contaminant concentrations were below levels shown to adversely affect the environment or human health. The remaining 749 sites are undergoing some type of response action or require further evaluation.

ATSDR reviewed the available information to determine sources of contamination, potential pathways of contaminant migration, and potential points of human exposure to those contaminants. The evaluation concluded that the community has not been exposed to PHNC-related contaminants at levels where harm to human health has been observed. ATSDR specifically identified and evaluated five public health issues related to potential exposure to environmental contaminants on PHNC. The generalized findings are summarized below. Later sections of this report describe in more detail how ATSDR reached these conclusions.

- *Can incidental environmental exposure to contaminants in surface soils within the PHNC or nearby area result in adverse health effects?* ATSDR identified four sites where people could come into contact with contaminants in the surface soil. Those sites are the Pearl City Peninsula landfill, the Waipahu ash landfill, the former pesticide mixing area, and Waipio Peninsula transformer W-11. ATSDR concludes that incidental, short-duration exposures to the contaminants found at those sites did not in the past, and do not now, pose a human health threat.

- *Have spills or releases at various locations at PHNC resulted in contamination of drinking water supplies at levels that might result in adverse health effects?* ATSDR identified two sites—the Ewa Junction Fuel Drumming Facility and the Red Hill Oily Waste Disposal Facility—where contaminants were detected in the shallow groundwater. ATSDR evaluated those sites to determine if drinking water supplies could be affected by the contamination. The results indicate that contaminants spilled or released had reached the shallow groundwater. However, this groundwater source is not suitable for, and is not used for, drinking water. The contaminants have *not* reached, and are unlikely to reach, the deeper aquifer used to supply drinking water.

- *Have spills or releases of volatile or semivolatile compounds resulted in human exposure to airborne contaminants at levels that might result in harmful health effects?* ATSDR identified one site that represented an environmental pathway of human exposure to indoor

airborne contaminants. Volatile compounds used and released at the Aiea Laundry resulted in indoor air contamination in a nearby church and school. ATSDR completed the initial evaluation of this site in 1996; this current public health assessment evaluated the additional information collected since that time. ATSDR concluded that the low levels of indoor air contamination that resulted from releases at the Aiea Laundry do not pose a past, current, or potential future health hazard for the church staff, students, and members.

- *Are fish and crabs collected from Pearl Harbor safe to eat?* ATSDR reviewed and evaluated the levels of contaminants measured in samples of fish and crabs collected from Pearl Harbor. The Hawaii Department of Health issued an advisory in 1998, cautioning against the consumption of fish and crabs collected from Pearl Harbor. ATSDR evaluated the level of contaminants found in the fish and crab samples and concluded that the polychlorinated biphenyl (PCB) concentrations were elevated. Therefore, ATSDR supports the Hawaii Department of Health advisory to avoid eating fish and shellfish from Pearl Harbor.

- *Can incidental exposure to Pearl Harbor sediments result in harmful health effects?* ATSDR evaluated the contaminant levels measured in sediments throughout Pearl Harbor and concluded that the contaminant concentrations were too low to be of health concern for anyone incidentally ingesting or touching Pearl Harbor sediments.

Background

Overview

The Pearl Harbor Naval Complex (PHNC) is an active Navy installation located on Oahu, Hawaii. Many on-base sites have been contaminated as a result of previous operations, and past chemical spills and material disposal practices at PHNC. The Agency for Toxic Substances and Disease Registry (ATSDR) conducted this public health assessment (PHA) to identify whether community members could come into contact with PHNC-related environmental contaminants at levels that could cause adverse health effects. This document describes the relevant information used in the evaluation along with the results and conclusions.

Site Description and Operational History

Topography and Land Use

The island of Oahu, Hawaii, consists of an upland area composed of two nearly parallel volcanic mountain ranges (Ko'olau and Wai'anae) that trend northwest and define, respectively, the northeast and southwest coastal margins of the island (Figure 1). In central Oahu, lying between the two volcanic complexes, the Leileihua (or Schofield) Plateau extends from the northern fringes of the PHNC northward toward the northwest shore of the island.

For about 150 years, the Leileihua Plateau represented a large area of agricultural development, including cultivation of sugar cane and pineapple. A few small communities and the U.S. Army Schofield Barracks facility are located in the central portion of this plateau. Urbanization of portions of the southern fringe of the plateau to the north and northwest of Honolulu began in the 1990s. Sugar cane production ceased on Oahu in 1996.

Pearl Harbor, the PHNC, and the city of Honolulu are located on a broad coastal plain that extends from Diamond Head (on the southeast end of the Waikiki Beach area) northwest along the south coast of Oahu to the Ewa Plain and the Barbers Point area. PHNC adjoins and is largely surrounded by Honolulu, the state capital, a city of over 400,000 people. Pearl Harbor and the PHNC are located about 5.8 miles northwest of the downtown district of Honolulu (Navy 2003).

Pearl Harbor (Figure 2) is separated by the Pearl City and the Waipio peninsulas into three separate arms named East Loch, Middle Loch, and West Loch. Because of the long history of the Navy's use of the harbor, the facilities surrounding the harbor have expanded and evolved over time with the changes of the Navy's mission and weapon systems use. Since PHNC's establishment, six major activities have evolved there (Navy 2003):

- **Naval Station Pearl Harbor** (NAVSTA) controls the waters of Pearl Harbor and many noncontiguous and submerged lands in and around the harbor. About 4,960 acres of harbor and 830 acres of land are under NAVSTA control. The land-based facilities include the main base area, Ford Island, and numerous outlying facilities that are not contiguous with the shoreside lands managed by the Navy.

- **Naval Submarine Base, Pearl Harbor** (SUBASE) occupies 123.5 acres of land adjoining East Loch. SUBASE provides berthing, maintenance, and support facilities for submarines in port.

- **Fleet and Industrial Supply Center, Pearl Harbor** (FISC) occupies six noncontiguous areas totaling about 800 acres. FISC provides supplies and logistics support for the fleet and shore-based Navy facilities. FISC manages the largest bulk fuel storage facility in the Pacific.

- **Naval Shipyard and Intermediate Maintenance Facility** (NAVSHIPYD&IMF; the former Naval Shipyard, Pearl Harbor—NAVSHIPYD) is located on about 115 acres within the main base facilities. These industrial facilities supply major ship repair and overhaul services.

- **Naval Facilities Hawaii** (NAVFAC HI: Naval Facilities Engineering Command Hawaii—formerly PWC) is located on 71 acres of land located about 1 mile east of the main PHNC complex. NAVFAC HI provides maintenance and repair to Navy family housing complexes and utilities. It also provides engineering, planning, and public works services to PHNC.

- **Naval Magazine Pearl Harbor** (NAVMAG PH; the former Naval Magazine Lualualei—NAVMAG) is composed of three noncontiguous facilities supplying ordnance support to the Army, Navy, and Air Force commands located on Oahu. The West Loch Branch is the only facility of the three that is located at the PHNC. The West Loch Branch occupies about 4,092 acres adjacent to the West Loch. Of that total, about 1,425 acres of the complex are located on the Waipio Peninsula. The West Loch Branch supplies facilities for off-loading, storage, and loading of ordnance.

Also located within the PHNC area is the Naval Sea Systems Command Detachment, Inactive Ship On-Site Maintenance Office (NISMO). This facility occupies about 14 acres along the northwest shore of Middle Loch.

Operational History

U.S. Naval operational history began in 1899, with the establishment of Naval Station, Honolulu, which became Naval Station, Hawaii, the following year (Earth Tech 2004a). Initially the station consisted of about 800 acres of land surrounding the harbor, obtained from the Hawaiian monarchy for development of naval facilities (Ogden 1995). From 1901 to 1911, the harbor was dredged, the entrance channel was enlarged, and shore facilities were developed. The objective of this extended period of dredging and development was to ensure that the harbor would be usable by the largest ships (Earth Tech 2004a).

In the following years, the naval presence grew, additional land was obtained, and the development of the naval facilities continued. In 1918, the U.S. government obtained Ford Island and developed it as a landing field for aircraft (Earth Tech 2004a). After the attack on December 7, 1941, industrial activity at PHNC increased dramatically. Since that time, the number of personnel stationed at PHNC has fluctuated with the demands of wars and global tensions, and facilities have been added or modified to accommodate those needs (Earth Tech 2004a).

Remedial and Regulatory History

The Navy conducted an initial assessment study of PHNC in 1983. From historical data, site inspections, and interviews of personnel, that assessment identified 35 potentially contaminated sites (Navy 1983). After consultation with the U.S. Environmental Protection Agency (EPA), Region 9, the Navy conducted further investigations at many of the identified sites. Using its Hazard Ranking System, EPA evaluated the PHNC in 1991, and placed it on the National Priorities List (NPL) of hazardous waste sites on October 14, 1992. As a result of that listing, a Federal Facilities Agreement (FFA) was entered into between the Navy, EPA, and the State of Hawaii on June 10, 1994 (Navy 2003). The Hawaii Department of Health (HDOH) was named in the FFA to represent the interests of the state of Hawaii.

The terms of the FFA require thorough investigation of the environmental effects of past and present activities conducted at PHNC and that remedial actions be taken, as necessary, to protect public health, welfare, and the environment. The FFA also requires compliance with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), and other relevant federal and state laws.

Since 1994, numerous remedial investigations have taken place throughout the PHNC and those investigations are still ongoing. By June 2002, the Navy had evaluated 5,197 sites, of which 4,448 were determined to be “no further action required” sites. The remaining 749 sites are either undergoing some type of response action or require further evaluation (Navy 2003).

Due to the size and diversity of the Naval complex, EPA, HDOH, and the Navy divided PHNC into 18 geographic study areas (GSAs). At six of the GSAs, the extent of environmental contamination is well characterized and the remediation projects are underway or completed. Those sites include the Ewa Junction, Pearl City Junction, Aiea Laundry, Manana Storage, Red Hill, and Pearl Harbor Sediment Study sites.

The remaining 12 GSAs (Figure 2) have been addressed in separate site summary evaluations. Site summary evaluations are comprehensive compilations of available information on the potential release of hazardous substances that could have an adverse effect on human health or the environment. The results of the site summary evaluations are presented in comprehensive site summary reports (SSRs). These reports have been used to

- identify immediate response needs;
- assess the degree of human health or ecologic risk associated with sites or potential release locations within the GSA;
- assess whether individual sites or potential release locations need further investigation or if the site or location can be placed in the “no further response action required” category; and
- identify, for sites needing further action, potential candidates for removal action or remedial investigation (RI).

ATSDR has reviewed all the SSRs and examined the listing of the sites included in the "Environmental Condition of Property" tables. The sites evaluated in this PHA are sites that ATSDR has determined may represent a potential pathway of human exposure to contaminants.

Climate

The climate of PHNC is, as is most of Hawaii, remarkably uniform. The tropical climate consists of two seasons. The summer months are May through September, when the midday sun is almost directly overhead and the trade winds blow from the northeast 80 to 95 percent of the time with an average wind speed of 11.6 miles per hour. The winter months are October through April, when the temperature is cooler, the sun is lower in the sky, the trade winds blow from the northeast 50 to 80 percent of the time, and rain is more prevalent in some locations (Oki and Brasher 2003, Navy 2003).

The annual mean variation in monthly temperatures is only about 9°F for areas near sea level, such as PHNC (maximum elevation 100 feet). The warmest month is August, with a mean temperature of 80.5°F; the coolest month is February with a mean temperature of 72°F (Oki and Brasher 2003). Rainfall near PHNC ranges from about 1 inch per month in mid-summer to as much as 4 inches per month in the midwinter months. The mean annual rainfall is about 25.5 inches. However, the rainfall readily evaporates from the soil or is removed through absorption by trees and other plants (Navy 2003). That diminishes the downward migration of water in the local soil.

Geology

The mid-Pacific Hawaiian Islands were formed from numerous volcanoes that have evolved through time (Oki and Brasher 2003). The geology of Oahu is a function of the formation and erosion of two main volcanic masses. During the formation process, volcanic flows can be broken by fractures or rifts that become pathways for future intrusive igneous dikes. The dikes are typically massive, near-vertical, dense sheets of basalt that are typically about 10 feet thick. The dikes, unlike the flow rocks they penetrate, are impermeable and can greatly affect the migration of groundwater. Dikes may comprise as much as 5 percent of the volcanic shield mass.

Deeply incised valleys formed during the erosion of the original volcanoes. Many of the valleys were filled with alluvial deposits (gravels, sands, and silts). Subsidence of the volcanic masses, coupled with erosion and sea level changes over time, have resulted in a coastal plain that extends about 5 miles inland in the Ewa area, west of Pearl Harbor (Oki and Brasher 2003). These coastal plain sedimentary deposits are composed of terrestrial and marine alluvium and calcareous reef deposits. They underlie the West Loch, Ford Island, and portions of the Waipio Peninsula and the Shipyard—Halawa Main Gate portions of the PHNC. These deposits, like the volcanic dikes, have important effects on the movement of groundwater (Figure 3).

Surface Water Hydrology

Streams originate in the mountainous interiors of the Wai'anae and Ko'olau Ranges and flow to the ocean. Some of the streams in the island's interior, in the dike-intruded areas, in the wetter windward areas, and in the coastal areas with high water tables are perennial (year round) streams and flow throughout their course (Oki and Brasher 2003). Pearl Harbor is formed at the confluence of several drowned river valleys.

The Harbor area receives runoff from seven watersheds: Waikele, Waiawa, Waimalu, Aiea, Halawa, Honouliuli, and Ewa Beach. The largest drainage basin, the Waikele watershed, originates in the central Oahu Schofield Plateau and comprises about 40 percent of the Pearl Harbor drainage basin area. This watershed discharges the greatest sediment load into the harbor (Navy 2003).

Because of urban, industrial, and agricultural influences within the watersheds of the PHNC, the streams, in addition to their natural load of sediment, dissolved metals, and other soluble constituents, also carry variable levels of herbicides, pesticides, and other contaminants into the harbor (Oki and Brasher 2003).

Major wetlands exist within and near PHNC. These wetlands include all the natural shorelines and areas in the Waipio and Pearl City Peninsulas, Laulaunui Island, Ford Island, and Makalapa Crater. In addition, there are wetlands in the Waiawa and Honouliuli Units of the Pearl Harbor National Wildlife Refuge (Navy 2003).

Hydrogeology

On Oahu, groundwater is the source of almost all drinking and other domestic use water. The source of the groundwater is rainfall. Most of the groundwater is found in the volcanic rocks, which are generally quite porous and permeable. However, dense, low-permeability volcanic dikes and massive lava flows can control the areas where groundwater is found and modify groundwater flow direction. Marine and terrestrial coastal sediments, old alluvial valley fill, and zones of weathered volcanic rock can also impede the flow of groundwater.

> An *aquifer* is a geologic formation or group of formations that are water bearing.

On Oahu, freshwater groundwater is typically found in the volcanic flow rocks. A freshwater aquifer used for drinking water slopes gently from the mountainous, upland areas downward to sea level or locally, toward the level of perennial streams in the lower reaches of the stream valleys (Figure 4). The upper limit of the lens-shaped groundwater aquifer is defined by the water table surface. The base or lower limit of the freshwater lens is a transition zone of brackish (slightly salty) water underlain by saltwater.

Local variations in the permeability of the volcanic rock overlying this aquifer may create isolated zones of saturation in the otherwise unsaturated rocks. These isolated groundwater bodies, generally small in size and volume, are known as perched groundwater bodies or perched groundwater lenses. These perched systems are generally not developed to supply domestic water because they do not contain enough water to meet the domestic needs or the water quality is poor.

Water levels in the freshwater lens system in the Honolulu and Pearl Harbor area generally range from about 25 to 30 feet above sea level inland to about 15 to 25 feet above sea level near the coast (Hunt 1996). The low-altitude springs near Pearl Harbor are areas of natural groundwater discharge (Visher and Mink 1964). Because the permeability of the coastal plain sediments is generally low, these sedimentary deposits create a confining layer on top of the basal aquifer. Further south, in areas underlain by coastal plain sedimentary deposits (locally referred to as "caprock"), the freshwater lens system in the basalt flows is confined, creating an artesian condition (Hunt 1996).

Much of the domestic drinking water is pumped from this freshwater lens system in the Honolulu area from wells near Pearl Harbor, and from the dike-impounded freshwater body in the Schofield Plateau area of central Oahu, where the groundwater is several hundred feet thick.

In central and southern Oahu, large areas were devoted to the cultivation of sugar cane and pineapple. Sugar cane required relatively significant quantities of irrigation and the use of fertilizers, herbicides, insecticides, rodenticides, growth regulators, and fumigants. Even though cultivation of pineapple requires much less irrigation water than sugar cane, it entails the use of fertilizers, soil fumigants, fungicides, herbicides, insecticides, growth regulators, and nematicides.

Excess irrigation water that infiltrates below the root zone of these and other agricultural crops is a source of local groundwater recharge. Those agricultural chemicals that are not used by the crop, tightly bound to the soil, evaporated, or rapidly degraded are potentially transported downward with the infiltrating irrigation water to the water table. These agricultural chemicals are potential sources of groundwater contamination.

Wastewater resulting from industrial activities and other urban activities such as residential lawn care (fertilizers, pesticides, etc.) and sewage disposal also potentially affects the quality of groundwater in the southern Oahu groundwater system. Most wastewater generated in the developed, nonagricultural areas is collected in sanitary sewers and pumped to wastewater treatment plants.

Most of the treated wastewater effluent is discharged to the ocean through outfalls that release the effluent offshore. Some of the treated wastewater is injected into disposal wells, discharged to surface water bodies, pumped to leach fields or evaporation ponds, or used for irrigation at locations such as golf courses. Most injection wells are located seaward (downgradient from) the underground-injection control (UIC) line. HDOH established this line to protect the quality of Oahu's groundwater and the health of its populace (Oki and Brasher 2003). Generally, the only producing wells (wells withdrawing groundwater) are artesian wells below the UIC line. This prevents landward encroachment or intrusion of the basal saltwater into areas that underlie the freshwater-lens system.

Most of the PHNC lies seaward of the UIC line, except the north shore of the East Loch, which is not part of the PHNC installation. Thus, there are no producing drinking water wells within the main area of the PHNC. A few municipal water wells operated by the Honolulu Board of Water Supply are located near some of the outlying PHNC facilities, such as Red Hill. The quality of the water produced by a well located near the Red Hill facility will be discussed later in this assessment.

ATSDR Involvement

ATSDR conducted an initial site visit to PHNC on May 18–22, 1992. The purpose of the visit was to (1) identify information necessary for initiating the public health assessment process at the base, (2) determine whether people were being exposed to hazardous materials at levels of concern for short- and long-term health effects, and (3) collect available information to prioritize ATSDR health assessment activities. ATSDR staff met base representatives, toured the installation and surrounding areas, and collected information about community health concerns. ATSDR considered possible past, current, and future exposure pathways and determined, at that time, that no immediate or long-term public health hazards appeared to exist at PHNC.

ATSDR revisited PHNC on January 18–20, 1996. During that visit, ATSDR reviewed the progress made by the many remedial investigations underway at that time. To address a specific public health concern at the outlying Aiea Laundry facility, ATSDR prepared a health consultation. Of concern was whether past releases of volatile organic compounds (VOCs) at the site posed a health risk to elementary school children, teachers, church staff, and church members, who attended the nearby St. Elizabeth Church and School and Aiea Elementary School. ATSDR concluded that the exposure to low levels of VOCs did not represent a health concern (ATSDR 1996a).

Also in 1996, ATSDR was asked to evaluate whether the arsenic levels remaining in the soils after arsenic-contaminated surface and subsurface soils were removed from the former Manana Storage Area would represent a public health hazard. ATSDR determined that the arsenic-contaminated soil removal activities conducted by the Navy had been thorough and that the planned future uses of the former Manana Storage area near Ewa Junction would not result in harmful health effects (ATSDR 1996b).

On January 12–15, 2004, ATSDR again conducted a site visit of PHNC. The objectives of that visit were to (1) collect information gathered by the recent PHNC investigations, (2) visit several sites of potential public health concern, and (3) determine what public health issues or concerns should be evaluated in the PHNC PHA.

Demographics

ATSDR examines demographic data (i.e., population information) to determine the number of people potentially exposed to environmental chemicals. It also uses the information to determine the presence of any sensitive populations, such as women of childbearing age, children, and the elderly (Figure 5). Demographic data also provide details on population mobility, which in turn, help ATSDR evaluate how long residents might have been exposed to environmental chemicals.

Quality Assurance and Quality Control

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. Documents prepared for the CERCLA program must meet standards for quality assurance and control measures for chain-of-custody, laboratory procedures, and data reporting. The environmental data presented in this PHA come from site characterization, remedial investigation, and groundwater monitoring reports prepared for the PHNC, the City and County of Honolulu, and others under CERCLA and the Resource Conservation and Recovery Act (RCRA). ATSDR has determined that the quality of environmental data available for the PHNC is adequate for making public health decisions.

Many of the important documents ATSDR reviewed and referenced in the preparation of this PHA include analytic data that record positive, quantified detections of targeted chemicals or analytes. These analytical results also typically include results that are "qualified," judged questionable for a variety of technical reasons, or labeled as "not detected." In the tables of analytical results presented in this PHA, ATSDR recorded the quantified detections and did not include the data that were judged questionable.

Evaluation of Exposure Pathways

Introduction

What is meant by exposure?

ATSDR's PHAs evaluate the potential for human exposure, or contact, with environmental contaminants. Chemical contaminants released into the environment have the potential to cause adverse health effects. However, *a release does not always result in human exposure*. People can only be exposed to a contaminant if they come in contact with it—if they breathe, eat, drink, or come into skin contact with a substance containing the contaminant. If no one comes into contact with a chemical, then no exposure occurs, thus no health effects could occur. Often the general public does not have access to the source area of the environmental release. This lack of access becomes important in determining whether people come into contact with the environmental contamination.

ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a chemical. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or skin contact with a substance containing the chemical.

> The five elements of an exposure pathway are: (1) source of contamination, (2) environmental medium, (3) point of exposure, (4) route of human exposure, and (5) receptor population. The source of contamination is where the chemical was released. The environmental medium (i.e., groundwater, soil, surface water, air, etc.) transports the chemical. The point of exposure is where humans come in contact with the contaminated medium. The route of exposure (i.e., ingestion, inhalation, dermal contact, etc.) is how the chemical enters the body. The persons actually exposed are the receptor population.

A *completed pathway* exists when the five elements of a pathway connect a source of contamination to people who are exposed to that contaminant. If contaminants migrate from a source area to a point where people can contact them, a completed pathway of exposure could exist. In addition, completed pathways are likely to occur when people enter source areas. A *potential pathway* exists when information on one of the five elements is missing.

How does ATSDR determine which exposure situations to evaluate?

ATSDR evaluates site conditions to determine if people could have been, are, or could be exposed (i.e., exposed in a past scenario, a current scenario, or a future scenario) to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, sediment, water, air, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation.

Exposure does not always result in harmful health effects. If exposure was, is, or could be possible, ATSDR considers whether contamination is present at levels that might affect public health. ATSDR selects contaminants for further evaluation by comparing them against health-based comparison values (CVs). ATSDR develops these from available scientific literature related to exposure and health effects. CVs are derived for each medium and reflect an estimated contaminant concentration that is *not likely* to cause adverse health effects. CVs are specific for a given chemical, and are based on a standard daily contact rate (e.g., an amount of water or soil consumed or an amount of air breathed) and body weight.

Comparison values are derived using conservative exposure assumptions, reflecting concentrations much lower than those observed to cause harmful health effects. Thus, CVs are protective of public health in essentially all exposure situations. As a result, *concentrations detected at or below ATSDR's CVs are not a public health concern*.

CVs are not thresholds for adverse health effects. While a concentration at or below the relevant CV could reasonably be considered safe, it does not necessarily follow that any environmental concentration exceeding a CV would produce harmful health effects. Exposures that exceed CVs are further evaluated as described in the next section.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/HAGM or by contacting ATSDR at 1-888-42-ATSDR. Appendix A defines some of the technical terms used in this health assessment.

If someone is exposed, will they get sick?

Exposure, even to contaminants at concentrations above comparison values, does not always result in harmful health effects. Exposures that exceed CVs are further evaluated to determine whether the exposure would be expected to cause health effects and identify the type and severity of health effects expected. The potential health effects that could follow an exposure depend on the exposure concentration (how much), the frequency of exposure (how often), duration of exposure (how long), and route or pathway of exposure (breathing, eating, drinking, or skin contact). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur.

In almost any situation, there is considerable uncertainty about the true level of exposure to environmental contamination. To account for this uncertainty and to be protective of public health, ATSDR typically uses conservative, worst-case exposure level estimates as the basis for determining whether adverse health effects are possible. These estimated exposure levels usually are much higher than the levels to which people are really exposed. If the exposure levels indicate that adverse health effects are possible, ATSDR performs a more detailed review of the exposure, also consulting the toxicologic and epidemiologic literature for scientific information about the health effects from exposure to hazardous substances.

How does ATSDR evaluate potential exposures?

To evaluate exposures to contaminants, ATSDR examined available data to determine whether chemicals were above ATSDR's CVs. For those that did exceed CVs, ATSDR derived exposure doses (see text box for definition) and compared them against health-based guidelines,

An exposure dose is the amount of chemical a person is exposed to over time.

including ATSDR’s minimal risk levels (MRLs) and EPA’s reference doses (RfDs). For cancer effects, ATSDR compared an estimated lifetime exposure dose to available cancer effect levels (CELs) and reviewed genotoxicity studies to further understand the extent to which a chemical might be associated with cancer outcomes. Estimated exposure doses that are less than health guideline values are not considered to be of health concern. If estimated doses are higher than the health guideline values, ATSDR further examined the chemical-specific health effect levels discussed in the scientific literature and more fully reviewed exposure potential. This information was used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness. As stated previously, exposure to a certain chemical does not always result in harmful health effects. The type and severity of health effects expected to occur depend on the exposure concentration, the frequency and duration of exposure, the route or pathway of exposure, and the multiplicity of exposure. Please see Appendix B for more details on the methods and assumptions ATSDR used to estimate human exposure doses and determine health effects.

Evaluation of Public Health Issues or Concerns

Introduction

In this section of the PHA, ATSDR evaluates environmental data to determine whether releases of contaminants to the environment pose health threats to people working or living at or near PHNC.

The issues or concerns evaluated in this section were identified in several different ways. ATSDR asked individuals who are familiar with the site, what they thought were significant issues or community concerns. ATSDR reviewed the community concerns identified and summarized in the numerous site-related documents including the Community Involvement Plan (Earth Tech 2004a). In addition, ATSDR met with Navy, HDOH, and EPA officials to identify community concerns that should be considered for review. ATSDR reviewed available site documents to determine sources of contamination, potential pathways of contaminant migration, and potential points of human exposure to those contaminants. Finally, during the ATSDR site visits to PHNC, ATSDR observed sites and became aware of situations that needed further evaluation.

The public health issues and community concerns are presented in the following format: (1) each issue or concern is stated, (2) a brief summary of ATSDR's conclusions is presented, and (3) the information that ATSDR considered in formulating its conclusions is discussed in detail. Table 1 summarizes the pathways of environmental exposure evaluated in the following sections of this PHA.

Table 1. Summary of Pathways Evaluated in This Public Health Assessment

Pathway Names		Exposure Pathway Elements					Comments
		Potential Sources of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Exposed Population	
Completed Exposure Pathways							
Surface Soils	Pearl City Peninsula Landfill	Disposal of ash & other industrial & municipal wastes	Surface soils	Burn disposal area & black sands area	Incidental ingestion & dermal contact	Trespassers	Maximum exposure scenario assumed & evaluated
	Waipahu Ash Landfill	Disposal of ash & other industrial & municipal wastes	Surface soils	Landfill margins prior to reclamation	Incidental ingestion & dermal contact	Trespassers	Maximum exposure scenario assumed & evaluated
	Former Pesticide Mixing Plant	Accidental releases of pesticides during mixing, storage, & loading activities	Surface soils	Surface soils near shoreline	Incidental ingestion & dermal contact	Trespassers	Maximum exposure scenario assumed & evaluated
	Waipio Peninsula Transformer W-11	Releases of polychlorinated biphenyls (PCBs) near the transformer	Surface soils	Surface soils	Incidental ingestion & dermal contact	Pedestrians	Exposure to soils near the sites evaluated
Indoor & Outdoor Air	Aiea Laundry	Volatile organic compound (VOC) use & releases at laundry	Indoor air	Air in St. Elizabeth Church & school	Inhalation	Students, staff, & church members	Levels of VOCs in indoor air evaluated
Pearl Harbor Food Chain	Fish & Crabs	Agricultural, residential & industrial waste water, & runoff releases	Food chain	Fish & crabs caught in harbor	Ingestion	Seafood consumers	Realistic fish consumption evaluated
Pearl Harbor Sediments	Bottom Sediments	Agricultural, residential, & industrial waste water & runoff releases	Sediment	Near-shore harbor sediments	Incidental ingestion & dermal contact	Fishermen & recreational use of shoreline	Exposure to near-shore sediments evaluated
Potential Exposure Pathways							
Drinking Water	Ewa Junction Fuel Drumming Facility	Motor gasoline release from underground storage tank	Groundwater	Deep drinking water wells in deep aquifer	Ingestion	None	No exposure resulted, contamination is confined to the upper aquifer
	Red Hill Oily Waste Disposal Facility	Oily sludge disposal in pit	Groundwater	Deep drinking water wells in deep aquifer	Ingestion	None	No exposure resulted, contamination is confined to the upper aquifer

Public Health Evaluation

Issue 1: Can incidental, environmental exposure to surface soils, especially those containing polychlorinated biphenyls (PCBs), dioxins, or pesticides, within the PHNC or in nearby off-site locations result in adverse health effects?

Conclusions

During the January 2004 site visit to PHNC and in the initial review of site documents, ATSDR determined that potential pathways of human exposure to contaminants in the surface soils may exist or may have existed at four locations on PHNC or nearby off-site locations. These include Pearl City Peninsula landfill, Waipahu ash landfill, the former pesticide mixing area, and Transformer W-11. ATSDR evaluated these potential exposures to determine if they pose a human health hazard. Results of the analysis indicate that short-term exposure to some PHNC-related environmental contaminants was possible, but the resulting exposures were below levels that would be expected to cause health effects. A summary of each evaluation is given below.

Pearl City Peninsula Landfill

ATSDR visited the former Pearl City Peninsula landfill (PCPLF) in 2004. During this site visit, ATSDR did not specifically note areas of potential public health concern. However, given the long period of operation and the diverse character of wastes deposited there, ATSDR determined that a more detailed evaluation was necessary. The following discussion provides a summary of the previous investigations of PCPLF and a determination of the potential human health effects that might result from exposure to site-related contaminants.

Site Description

PCPLF is located on the northwestern portion of the Pearl City Peninsula, southwest of Pearl City, Oahu (Figure 6). The former landfill site occupies about 67 acres, bounded on the west by the Waiawa Unit of the Pearl Harbor National Wildlife Refuge and the Middle Loch of Pearl Harbor, on the south by the inactive Pearl City Municipal Sewage Treatment Plant, on the east by the Waiawa Stream, and on the north by a 40-foot-wide abandoned railroad right-of-way now used as a bicycle path (Figure 7).

A chain-link fence that surrounds the landward side of the site limits access to the landfill. A paved road and a bridge over the Waiawa Stream provided access to the site when the landfill was in operation. That bridge collapsed, but was rebuilt in 1999, in the same location. The bridge now provides restricted access to the landfill from the east side of the site. The remnants of a vehicle wash rack are located west-southwest of the former access gate. Access from the east was closed in 1992. Currently, restricted access is also possible through a gate on the north side of the site. The landfill could be accessed from Middle Loch, but there is no evidence of use of an over-water access route. Since closure, PCPLF has only been used by the occasional refuge and remediation investigation worker, who walks or drives across the landfill area. The frequency of trespassing at the PCPLF area is unknown, but historical evidence suggests that exposure to site contaminants was limited.

The former landfill is covered by a 1.5- to 3-foot-thick silty gravel cover composed of crushed basalt rock. The surface of the gravel cover is relatively flat and well compacted. On the southwest side of the site, adjacent to Middle Loch and near the Waiawa Unit, an area of “black sand” was exposed at the surface.

The landfill site is surrounded by a constructed soil berm that served to contain the refuse deposited at the site. Investigations have determined that the berm is not continuous and is apparently absent adjacent to the Waiawa Unit, the Waiawa Stream, the sewage treatment plant, and adjacent to Pearl Harbor. Concrete debris and other rip-rap were placed on the landfill slope perimeter along the shoreline to stabilize the slopes and reduce the potential of erosion into the harbor (Navy 1999).

The Navy, from 1965 to 1976, operated PCPLF as an authorized sanitary landfill for the disposal of municipal and industrial waste. From the mid-1940s to 1965, the area was used unofficially to dispose both solid and liquid wastes (Ogden 1995). Waste disposal activities included burning, landfilling, and uncontrolled dumping. During the 1940s, ash from refuse incineration was deposited along the southeast side of the landfill in an area now known as the “burn disposal area” (Navy 1999). Ogden (1995) conducted a review of historical air photographs taken of the site from 1952 to 1965, and found that waste materials were placed in relatively small, semicircular areas along the eastern side of the site. The evidence also indicates that the debris was covered with soil taken from a nearby off-site location. Thus, during this 1952–1965 interval, the opportunity for exposure to landfill wastes appears to have been limited.

From 1965 to 1976, daily operations at PCPLF included digging a trench, filling it with waste material, and covering the wastes with soil or crushed coral (Ogden 1995). PCPLF’s gravel cap was apparently constructed shortly after the facility was closed in 1976, but a specific date for the completion of this cap has not been found.

Remedial Investigations and Actions

An RI was conducted at PHNC from December 1991 through March 1993; the RI report was released in September 1995 (Ogden 1995). The five preceding investigations established that the refuse in the landfill was mainly municipal solid waste and found VOCs, semivolatile organic compounds (SVOCs), and metals characteristic of municipal solid waste (Ogden 1995).

Subsurface drilling conducted for the RI found, depending on location, the top of the water table at depths ranging from about 4 to 14 feet below the PCPLF ground surface. Those borings also disclosed that the lower layers of landfill refuse now lie as much as 5 feet below the level of the water table. The shallow groundwater of this area is not suitable for use as drinking water. The only water wells used for drinking water supply or irrigation are hydraulically upgradient from PCPLF and are not affected by any groundwater contamination resulting from the landfill (Ogden 1995).

Evaluation of Potential Public Health Hazards

Landfill Surface Soils

Results of soil sampling performed across the landfill facility indicate that, with the exception of the burn disposal area and the black sands area, the surface soils of the landfill cap are relatively free of contaminants. Most of the samples were collected from the gravel landfill. They were found to contain low levels of VOCs, SVOCs, pesticides, and polychlorinated biphenyls (PCBs). ATSDR reviewed the available data and concludes that, *since the construction of the landfill cover at the PCPLF, the site does not pose a human health threat.* From 1952 to 1965, soil covers placed over waste materials deposited in that area limited the potential for incidental exposure, and therefore, the potential health threat.

Burn Disposal Area Soils

Subsurface soil samples collected near the former wash rack area disclosed the presence of incinerator ash and debris indicative of the area now termed the “burn disposal area.” Analysis of the surface and subsurface soil samples collected near the former wash rack found elevated concentrations of some PCBs, dioxin/furans, and metals that varied considerably between locations. Those detected chemicals described a pattern of “hot spots” of contamination over a large area to a depth of less than 2 feet (Figure 7) (Ogden 1995, Earth Tech 1998). Remedial activities included

- removal of the ash deposits discovered in the former sewage disposal plant site adjacent to the southeastern part of the site,
- consolidation of that ash with the PCPLF ash deposits, and
- installation of a clean gravel cap over the known extent of the PCPLF burn disposal area.

During the remedial work, additional deposits were identified and will be addressed by future removal actions (Earth Tech 1998).

ATSDR evaluated the levels of contaminants detected in the surface soil samples collected in the burn disposal area. The opportunity for human exposure to those contaminants has been very limited since the landfill was closed and capped, and access to the site was restricted. Before landfill closure, the potential for incidental exposure to the ash deposits may have been greater. However, because the measured contaminant levels in the surface soil are low, *ATSDR concludes that exposure to those ash deposits did not in the past, and does not now, pose a human health threat.*

Black Sands Area

In 1976, black sands, of unknown origin, were apparently deposited after the closure of the landfill, but before the construction of the landfill cover. The sands encompass an area of about 200 feet in diameter to a depth of 3 to 6 inches and consist of dark gray to black, vitreous, coarse to medium grain-size sandy material. Sampling results indicate some polycyclic aromatic hydrocarbons (PAHs), PCBs, and metals exist in the sands at concentrations that exceed regulatory standards (Ogden 1995; Earth Tech 1998). In general, these investigations indicated that the levels of contaminants found in the black sands did not constitute a human health threat due to direct contact. However, those deposits may erode and wash into Pearl Harbor and the underlying landfill refuse may be exposed. Remedial efforts include installing a soil cover or, in some locations, shotcrete (sprayed concrete) to provide erosion control (IT Corporation 2000; Earth Tech 1998).

Due to the coarse grain-size of the black sands, inhalation and incidental oral ingestion are unlikely. Dermal exposure could occur if individuals walk across these black sands, but again, the sand size of these deposits suggests that they do not adhere as well to bare skin as finer-grained deposits. Given the small size and isolated location of the black sand deposits, the opportunity for human exposure was, before covering, highly limited. On this basis, *ATSDR concludes that exposure to these black sand deposits in the past did not pose a human health threat.*

Waipahu Ash Landfill

During the January 2004 site visit to the Waipahu ash landfill (WALF), ATSDR investigated an area of what appeared to be ash and other landfill debris on a steep embankment near the Pearl Harbor shore. Erosion may have exposed this apparently isolated area of ash after the construction of the cap over these landfill deposits. Likewise the ash may not have been covered by the previous capping effort. In viewing this site, ATSDR also observed discarded beverage-container litter at the base of this embankment, suggesting relatively recent human recreational use of this location. ATSDR determined that because there was some level of human use of this site, an evaluation of whether human exposure to this landfill refuse and ash might result in adverse health effects was necessary.

Site Description

WALF is located on the Waipio Peninsula, Waipahu, Oahu (Figure 8). The 41-acre site is adjacent to the Waipahu Depot Road on the northeast side. Located across that road is the closed Waipahu Incinerator. The Kapakahi Stream follows the northwest side of the site and West Loch of Pearl Harbor lies along the west and south perimeter of WALF. With the exception of the closed incinerator site, the land on the south and east sides of WALF is PHNC property. Approximately the southern two-thirds of the WALF site are PHNC property and the northern third is held by the State of Hawaii.

WALF operated from the early 1960s until perhaps as late as March 1993. The City and County of Honolulu operated the facility as an open burn site where municipal solid waste was burned in place. Open burning ceased in 1970, when air quality standards were adopted. From 1970 until the completion of the Waipahu Incinerator in 1972, unburned municipal wastes were deposited at the WALF site. After the completion of the incinerator, only incinerator ash was deposited at WALF. By March 1993, apparently all of the ash from the Waipahu Incinerator was trucked to the Waimanalo Gulch Landfill, located several miles to the west of the incinerator site. The incinerator operated until 1994 (Barrett Consulting Group 1994; Earth Tech 1999, 2003, 2004b; Hartman 1993a).

The topography of the WALF site is relatively flat. However, the sides of the WALF site, adjacent to the Kapakahi Stream and the Middle Loch of Pearl Harbor, are steep and prone to erosion. A thin soil cover exists over the landfill ash in some areas, but most of the landfill surface has not been adequately covered (Earth Tech 1999). Rainfall runoff generally flows radially from the top of the landfill towards the steeply sloped sides and into Kapakahi Stream and West Loch. Groundwater flow beneath the landfill is toward the southwest, from the area of the former Waipahu Incinerator towards West Loch (Earth Tech 1999). The landfill does not affect the quality of any drinking water aquifer or drinking water supply.

Remedial Investigations and Actions

The previous monitoring studies performed at WALF and the Waipahu Incinerator have assessed the character of the groundwater, leachate generation, surface water quality, methane generation, marine sediments adjacent to the site, and ash generated at the incinerator (GMP Associates 1996; Hartman 1992, 1993a, 1993b, 1993c, 1994). More recent studies have investigated soil contamination (Table 2) (Earth Tech 2003).

The City and County of Honolulu have developed a large soccer park on the Waipio Peninsula on a large tract of land adjacent to WALF. That portion of the soccer park was completed and in use when ATSDR conducted the PHNC site visit in January 2004. Future development of the soccer park is planned for the northern third of the previous WALF. Additional studies have focused on developing a landfill cover that provides a suitable foundation for the soccer fields and to ensure that potential landfill releases, such as leachate or methane gas, do not result in environmental or human health hazards (Barrett Consulting Group 1994; Earth Tech 1999).

Evaluation of Potential Public Health Hazards

Low concentrations of metals were detected in the ash (Hartman 1992). Subsequent surface soil sampling detected various metals and one PAH at levels above ATSDR's CVs (Earth Tech 2003). Because of the physical character of the steep embankment and the presence of some surface vegetation, ATSDR determined that incidental inhalation to the exposed landfill deposits is unlikely. ATSDR did, however, evaluate the potential exposure resulting from incidental ingestion and dermal exposure to the landfill deposits. Although it is unclear how long some of the WALF ash deposits may have been exposed, ATSDR assumed that until the landfill was closed, only workers frequented the site. ATSDR assumed the opportunity increased for trespassing at the site after WALF was closed. On this basis, ATSDR determined that incidental environmental exposure to the WALF ash deposits may have begun as early as 1993, and continues at present—a potential exposure duration of 11 years. It is reasonable to assume that no individual would frequent the site for more than a few hours per week during that 11-year period.

Given these assumptions, ATSDR evaluated the potential health effects that might result from the use of the site a maximum of 4 hours per week, 52 weeks per year, for 11 years. This is considered to be the maximum exposure scenario for trespasser use of the site.

Table 2. Waipahu Ash Landfill Perimeter—Surface Soils Samples: Summary of Analytical Results

Analyte	*Range of detections*	*Comparison Value— ppm*			*Background*
		Child	*Adult*	*Source*	
Metals (ppm)					
Aluminum	15,500–44,000	100,000	1,000,000	Int. EMEG	NA
Arsenic	1.5–16.5	20	200	Chronic EMEG	22
Barium	23.9–213	4,000	50,000	Chronic EMEG	NA
Beryllium	0.52–2.2	100	1,000	Chronic EMEG	NA
Cadmium	**0.35–10.1**	**10**	100	Chronic EMEG	2.2
Chromium (total)	60.4–247	200	2,000	RMEG (Cr VI)	240
		80,000	1,000,000	RMEG (Cr III)	
Cobalt	22–210	500	7,000	Int. EMEG	NA
Copper	**62.2–28,800**	**1,000**	**10,000**	Int. EMEG	NA
Iron	**71,800–140,000**	**23,000**	**23,000**	Residential RBC	NA
Lead	**13.6–1,470**	**400**	**400**	SSL	23
Manganese	**135–3,560**	**3,000**	40,000	RMEG	NA
Mercury	0.43–0.81	20	200	RMEG (mercuric chloride)	0.25
Nickel	42.6–298	1,000	10,000	RMEG	320
Selenium	0.95–17	300	4,000	Chronic EMEG	NA
Silver	7.1–28.1	300	4,000	RMEG	NA
Thallium	**2.4–9.5**	**5.5**	**5.5**	Residential RBC	NA
Vanadium	**64.1–278**	**200**	2,000	Int. EMEG	NA
Zinc	117–799	20,000	20,000	Chronic/Int. EMEG	240
PAHs (ppb = 0.001 ppm)					
Benzo(a)pyrene	**4 (est.)–37,000**	**0.1**	**0.1**	CREG	NA
Fluoranthene	9–35,000	20,000	300,000	Int. EMEG	NA
Dioxin TEQ (ppt = 0.000001 ppm)					
2,3,7,8-TCDD	17.78–233.61	0.001	0.01	Int. EMEG	104

Bold values indicate detected value greater than a CV and the CV exceeded.
Not detected values are not included in this table. Because it only evaluates the positive detections, the evaluation is highly protective of the health of the general public and sensitive sub-populations.

CREG cancer risk evaluation guide
EMEG environmental medial evaluation guide
chronic: exposures lasting 1 year or longer
intermediate (Int.): exposures lasting more than 14 days and less than 1 year
NA not available
ppm parts per million
TEQ toxic equivalent
RBC risk-based concentration
RMEG reference dose media evaluation guide
SSL soil screening level
TCDD 2,3,7,8-tetrachlorodibenzo-p-dioxin

For those analytes that exceeded their corresponding CVs (Table 2), ATSDR determined potential exposure doses. While dermal exposure to metals is not a significant exposure pathway, dermal exposure to PAHs can result in adsorption of those compounds. Both incidental dermal and oral ingestion exposures were evaluated. On the basis of these evaluations, *ATSDR concludes that no adverse health effects are expected to have resulted from the short-duration exposures associated with trespassing at WALF.*

From its evaluation of WALF perimeter soils, Earth Tech (2003) recommended that where contamination levels exceeded cleanup levels, the soils should be excavated and placed beneath the landfill cap. Thus, potential exposure to those soils would be eliminated once they are covered by a properly designed cap. Construction of Phase II of the soccer park relies on the construction of this landfill cap. For this reason, *ATSDR concludes that the perimeter soils of WALF will not pose a potential health threat in the future. The completion of a properly designed landfill cap should ensure the future safety of the recreational users of the planned soccer park in this area.*

Former Pesticide Mixing Plant, Waipio Peninsula

ATSDR's 2004 site visit to PHNC included a tour of the former pesticide mixing plant on the Waipio Peninsula. During the tour, ATSDR noted evidence of trespassers. Given the long-term persistence of some of the contaminants likely present at this site, ATSDR determined that a more detailed evaluation was necessary. The following discussion provides a summary of ATSDR's analysis.

Site Description

The former pesticide mixing plant is located on the Waipio Peninsula, in Waipahu, Hawaii (Figure 9). The site occupies about 3.5 acres adjacent to Walker Bay, in the West Loch of Pearl Harbor, surrounded by land that was previously cultivated for sugar cane. Sugar cane cultivation on the Waipio Peninsula began about 1902. The Navy obtained the land between 1909 and 1948. Oahu Sugar Company leased the land from the Navy and continued to grow sugar cane until the late 1970s (BEI 2002).

The plant, operated by Oahu Sugar, was used to mix pesticide and fertilizer solutions. It consisted of unpaved access roads, an airstrip, a number of above-ground storage tanks (ASTs), and a Quonset hut. The pesticide solutions were transferred from mixing tanks to backpacks, trucks, and crop-dusting airplanes for application on about 1,700 acres of nearby cane fields. Former plant employees reported that they mixed dry pentachlorophenol powder in ASTs with water and diesel fuel to make an emulsion suitable for application in the cane fields (BEI 2002). Currently, there are no structures or ASTs remaining at the site. A 7-foot-tall chain-link fence surrounds the site, with padlocked gates on the southeast and north sides.

Remedial Investigations and Actions

Sampling results indicate dioxin, PAHs, pesticides, and metals exist in the soil at concentrations above ATSDR's CVs (Table 3; HDOH 1998; BEI 2002). The most frequent detections were of dioxins and furans, pesticides, and naturally occurring metals (BEI 2002). The persistent pesticide, dichlorodiphenyltrichloroethane (DDT), and the degradation and metabolic byproducts, dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD), were found throughout the site. Elevated levels of arsenic and lead were found at a few locations.

Evaluation of Potential Public Health Hazards

ATSDR further evaluated the compounds and metals shown in Table 3 to determine if they might pose a health hazard for individuals accessing the site. Although the pesticide mixing operations ceased at this location in the late 1970s, roads to the site have continued to provide unauthorized access to potential fishing sites along the shoreline of Walker Bay.

Trespassing at this site for access to fishing may have occurred at earlier dates when sugar cane was being grown nearby. Trespassing can now occur relatively unnoticed since the site is inactive. Thus, for the purpose of evaluating the potential public health implications of the casual use of the site, ATSDR assumed that such access has occurred for the last 30 years for adults and 6 years for children. Exposure doses were estimated for incidental, oral ingestion.

Trespassing for recreational purposes is difficult to evaluate because the frequency of the site use is unknown. ATSDR assumed that an individual might cross the site to fish at Walker Bay one day per week, every week of the year. ATSDR also assumed that people were exposed to the maximum concentration of the analytes detected. It is likely that these assumptions overestimate the potential exposures from use of the site, but for the purpose of evaluating the public health implications, the resulting estimates are highly conservative and protective evaluations.

The potential estimated doses of benzo(a)pyrene, pentachlorophenol, and arsenic were determined to be below levels of potential health effect. The levels of lead are somewhat elevated at the two surface soil sampling locations. However, because of the limited occurrence of elevated lead in the surface soils of the site, and because neither location is near the shoreline, it is unlikely that potential exposure to lead at the site is of health concern.

The estimated exposure dose of dioxins/furans, evaluated on the basis of the calculated toxic equivalent (TEQ) values, was determined to be safe for adults. For children, the calculated potential exposure to dioxins/furans at the site is of the same order of magnitude as the MRL (ATSDR 1998). Using the average concentration (0.085 ppm), the calculated exposure dose for children (1.5E-07 milligrams per kilogram per day (mg/kg/day)) is also on the same order of magnitude as the lowest-observed-adverse-effects level (LOAEL) derived from toxicological and epidemiological investigations (1.2E-07 mg/kg/day; ATSDR 1998). However, the exposure assumptions used were very conservative and it is highly unlikely that any adverse health effects would arise from exposure to the dioxins in the surface soils at this location. Thus, ATSDR concludes that incidental exposure to dioxins/furans is not likely to result in adverse health effects in children or adults who trespass at the former pesticide mixing plant.

Table 3. Former Pesticide Mixing Plant, Waipio Peninsula—Surface Soil Samples: Summary of Analytical Results Above Comparison Values

Analyte	*Range of Detections*	*Frequency (Detects/Total)*	*Comparison Values (ppm)*		
			Child	*Adult*	*Source*
Semivolatile Compounds (SVOCs—ppm)					
Benzo(a)anthracene	0.18 J–3.1	4/20	0.87	0.87	Residential RBC
Benzo(b)fluoranthene	0.11 J–8.0	11/20	0.87	0.87	Residential RBC
Benzo(a)pyrene	0.11 J–3.9	7/20	0.1	0.1	CREG
Pentachlorophenol	0.4 J–140	13/20	50	700	Chronic EMEG
Dioxins and Furans (Total TEQ—ppm)					
2,3,7,8-TCDD	0.00037–0.992	24/24	0.00005	0.0007	Int. EMEG
			0.001	0.001	ATSDR Action Level
Organochlorine Pesticides (ppm)					
4,4'-DDE	0.014 J–59.0	22/24	2	2	CREG
4,4'-DDD	0.003 J–42.0	14/24	3	3	CREG
4,4'-DDT	0.005–130.0	23/24	30	400	Int. EMEG
Metals (ppm)					
Arsenic	8.4 BG–55.3 BG	24/24	20	200	Chronic EMEG
Lead	10 B–960 G	24/24	400	400	SSL

Bold values indicate detected value greater than a CV and the CV exceeded.

Not detected values are not included in this table. Because it only evaluates the positive detections, the evaluation is highly protective of the health of the general public and sensitive sub-populations.

B estimated result; result is less than reporting limit and greater than the instrument detection limit
CREG cancer risk evaluation guide
EMEG environmental medial evaluation guide
chronic: exposures lasting 1 year or longer
intermediate (Int.): exposures lasting more than 14 days and less than 1 year
G elevated reporting limit; the reporting limit is elevated due to matrix interference
J estimated result; result is less than reporting limit
NA not available
PG The percent difference between the original and the confirmation analysis is greater than 40 percent
ppm parts per million
RBC risk-based concentration
RMEG reference dose media evaluation guide
SSL soil screening level
TEQ toxic equivalent

Because DDE and DDD are closely related degradation and metabolic byproducts of DDT, the levels of these compounds can be summed to evaluate the potential maximum exposure that might occur. When the maximum levels of DDE, DDD, and DDT detected at the former pesticide mixing plant are combined and the potential exposure dose estimated, the dose is below the level known to result in adverse health effects in adults. For children, the estimated exposure dose (0.00041 mg/kg/day) is below the MRL (0.0005 mg/kg/day; ATSDR 2002c). For this reason, ATSDR concludes that incidental exposure to DDT and related compounds at the former pesticide mixing plant is not likely to pose a health hazard for adults and children who trespass at the site.

The site is currently fenced and will be subject to remediation activities that will further limit the potential for human exposure to site-related contaminants. It seems unlikely that the future potential for exposure to site-related contaminants will be any greater than that presently occurring. For the reasons given above, *ATSDR concludes that incidental exposures to the contaminants at the former pesticide mixing plant resulting from trespassing are not a past, current, or potential future health threat.*

Waipio Peninsula, Transformer Site W-11

During the January 2004 site visit, ATSDR toured transformer site W-11 because of its location next to the paved bike and pedestrian pathway along the north shore of Pearl Harbor. During the site visit, children were observed walking along the path, apparently on their way home from school.

ATSDR performed the following evaluation to determine whether people are being exposed to PCB-contaminated soil at this site at levels that could cause health effects.

Accidental spills and some small-scale releases resulted in PCB contamination of some of the transformers' concrete bases and the soils near the transformers. To determine whether transformer sites were in need of cleanup, the Navy adopted the following cleanup goals: soil concentrations of no more than 1 mg/kg of PCBs and wipe samples from the concrete pads of no more than 10 micrograms per 100 square centimeters (µg/cm^2) of PCBs. Those cleanup goals are compatible with guidelines for transformers located in residential locations.

Site Description

PCBs were detected above established cleanup levels at the W-11 transformer site. The transformer, now removed, was located just south of the bike and pedestrian pathway and was enclosed by a tall, chain-link fence. Two dirt pathways pass near the transformer site. One, near the west side of the site led to the gate that provided access to the transformer. The other, to the east of the former transformer, leads down to the Pearl Harbor shoreline. Discarded beverage containers were observed along the shore below the eastern pathway. Natural brushy vegetation and brush piles cover much of the area near the transformer.

ATSDR concluded that occasional, recreational use was made of this shoreline location and the dirt path leading to that location. For that reason, ATSDR decided to evaluate whether incidental exposure to PCBs at this location could pose a health threat.

Remedial Investigations and Actions

Investigations of the W-11 transformer site were conducted in 2003 and 2004, and included detailed surface and subsurface soil sample analysis. As of August 2004, the W-11 site was remediated to 1 ppm PCBs. The contaminated soils excavated from the site were treated elsewhere using thermal desorption to 1 ppm PCBs or less. The transformer and pad were also removed (J.L. Fukumoto, Navy remedial project manager, personal communication, 2004).

The PCB contamination in surface soils at the site varied substantially, with the highest levels (60,000 mg/kg maximum within the fenced area) located near the transformer pad. Localized concentrations of PCB contamination were found to occur elsewhere. Because PCBs tend to bond tightly to soil and sediment particles, it is common to see the highest levels of contamination within the upper foot of soil.

Evaluation of Potential Public Health Hazards

Environmental exposure to PCBs at this location may have resulted from people occasionally using the pathways and nearby shoreline. To evaluate this potential exposure, ATSDR assumed the area was largely used by young adults engaging in recreational activities at the shoreline for no more that 1 day per week, over 6 years. The 6-year total exposure duration was developed from the assumption that most of the individuals using the area ranged in age from 12 to 18 years old. Because much of the site is covered with brush, ATSDR used the soil samples (0–0.5 feet) collected closest to the dirt paths for the evaluation. The PCB concentrations in those samples ranged from nondetect to 39 mg/kg.

The estimated exposure doses were less than ATSDR's chronic oral MRL of 0.00003 mg/kg/day. Therefore, this exposure is not considered to be of health concern.

When the use of the dirt path by children less than 6 years of age is considered, the estimated exposure dose (0.000069 mg/kg/day) is of the same order of magnitude as the MRL. However, the MRL is calculated using a large safety factor, and is two orders of magnitude below levels in which health effects were observed and recorded in the scientific literature (0.005 mg/kg/day; ATSDR 2000c). Therefore, exposures to children younger than 6 years are also below levels of potential concern.

ATSDR concludes that *the occasional use of these two dirt paths near transformer W-11 did not pose a health threat.*

ATSDR also reviewed the levels of PCB contamination found in samples collected from surface soil within 20 feet of the shoreline below transformer W-11. The average PCB concentration of those samples is 8.9 mg/kg, which, using the exposure scenario described above, also results in an estimated exposure dose (0.000016 mg/kg/day) that does not pose a health threat.

Finally, ATSDR examined the PCB levels detected in 13 surface soil samples collected adjacent to the paved bicycle path. PCBs were not detected in seven of those collected surface soil samples. The average value detected in the remaining six samples is about 7.8 mg/kg. It is reasonable to assume that school children might use this paved pathway as often as 300 days per year. A total of about 300 feet of this pathway is in the area potentially affected by PCB contamination, although the actual length of the segments affected by the contamination is much shorter than that total. If an individual walks very slowly, at a rate of 1 mile per hour (88 feet per minute), the roundtrip along this paved pathway would take less than 10 minutes.

In this evaluation, the exposures for adults and children are far below levels that might result in adverse health effects. This finding is, compounded by the fact the pathway is paved and the opportunity for incidental exposure to the nearby soils is negligible. Use of this pathway would not pose a health threat if it were used every day of the year and for much longer time intervals.

From the information reviewed above, *ATSDR concludes that incidental exposure to PCBs in surfaces soils near transformer W-11 did not pose a health threat in the past and, because the site has now been remediated, does not pose a current or future health threat.*

Issue 2: Have spills or releases at various locations at PHNC resulted in localized contamination of drinking water supplies at levels that might result in harmful health effects?

Conclusions

Past operations and spills at PHNC have contaminated the surficial aquifer at some locations. Those include a spill of motor gasoline (MOGAS) at the Ewa Junction Fuel Drumming Facility (EJFDF) and releases of oily wastes at the Red Hill Oily Waste Disposal Facility (OWDF) at Halawa Valley. ATSDR evaluated the sources of contamination and the hydrogeological characteristics of the surficial aquifers and underlying drinking water aquifers to determine whether drinking water supplies could be affected by these contaminant sources. Results indicate that the surficial aquifers are separate from the drinking water aquifers and therefore the drinking water sources will not be affected by these contaminants. The following section provides an overview of the evaluation and conclusions.

Ewa Junction Fuel Drumming Facility

Site Description

EJFDF is located north of the Middle Loch of Pearl Harbor (Figure 10). The 44-acre site was constructed in 1943, as a fuel drumming and transportation terminal. The facilities located on the site consisted of two 585,000-gallon (88 feet in diameter and 13 feet deep), concrete-lined underground storage tanks (USTs); a fuel drumming building (Building 9); and associated piping. The southern boundary of the site varies from about 250 to 700 feet north of the shoreline. The site has been inactive since the early 1970s (Earth Tech 2000a) and is presently overgrown with vegetation.

Several watercress farms are located immediately south of EJFDF. The ponds of those watercress farms lie topographically below the level of EJFDF, between the southern boundary of the site and the harbor. Watercress is grown in shallow (1–2 feet deep) ponds that are floored by a few inches of gravel. The ponds are flooded by about 3–4 inches of water from artesian wells on the site. Natural groundwater springs also occur in this area. Water from the artesian wells and springs is from the lower drinking water aquifer. Water from the ponds is released through outfalls to Pearl Harbor. A paved bicycle path parallels the harbor shoreline and separates the watercress farm area from the marsh and mangrove swamps along the harbor edge (Figure 11).

On March 12, 1971, vandals started the UST S-26 fuel pump, releasing an estimated 315,000 gallons of MOGAS to the ground surface near the UST. The next morning personnel found a pool of MOGAS 1–2 feet deep and about 150 feet in diameter. Navy personnel pumped as much of the pooled MOGAS as possible back into UST S-26. An estimated 32,000 gallons were recovered; the remainder infiltrated through the ground surface or evaporated (Earth Tech 2000a).

Remedial Investigations and Actions

Six detailed site investigations were conducted between 1971 and 1996 (Ogden 1996a; Earth Tech 2000a). The Navy drilled 24 monitoring wells at the site to delineate the extent of the subsurface MOGAS contamination. Six monitoring wells found MOGAS floating on the surficial aquifer. A maximum of 5 feet of free product was observed in a monitoring well drilled about 100 feet downgradient (south) of the UST. On the basis of this information, 16-inch diameter recovery wells were drilled; they ultimately succeeded in recovering significant quantities of fuel. In addition, the Navy constructed an interceptor trench in 1971 along the southern boundary of the site (Figure 11) to prevent off-site migration of the MOGAS fuel to the downgradient watercress farms and wetlands near the harbor. The recovery wells and the interceptor trench were operated for about 1 year. An estimated 100,500 gallons of MOGAS were recovered or lost to evaporation (Earth Tech 2000a).

By 1975, the measured thickness of free product was near zero in most of the affected area, except immediately downgradient of the UST. Free product was last observed in monitoring wells in March 1989, in a well located at the northeast end of the interceptor trench. Modifications to the interceptor trench and additional free product recovery activities were undertaken during this period to help minimize any additional migration of the released fuel.

Groundwater samples, collected in 1989, found MOGAS-related contaminants in the surficial groundwater beneath the site. At the same time, MOGAS-related contaminants were not detected in the groundwater samples collected from the artesian wells that feed the agricultural activities in the nearby watercress farm area. Subsequent groundwater sampling indicated significant natural attenuation was occurring as the contaminants migrated downgradient in the surficial aquifer (Ogden 1996a; Earth Tech 2000a). Elevated concentrations of lead were measured in the surficial groundwater at some off-site locations. The analysis of these samples is complicated by the highly turbid (muddy) quality of the groundwater; the lead could be attributed to the suspended sediments in the groundwater and not to MOGAS contamination. Samples from the three off-site artesian wells did not contain lead (Earth Tech 2000a). Together, these results indicate that the deep aquifer used for the watercress farm and as a drinking water supply has not been affected by site-related contaminants.

Results of the investigations indicate that some site-related contaminants have migrated beyond the trench, but only the groundwater in the surfical aquifer was affected. The investigations found no evidence that the MOGAS release at EJFDF had resulted in contamination of the deep aquifer downgradient of the site or the ponds of the watercress farms. The watercress ponds sit just above dense, silty clays that create a relatively impermeable barrier between the water-bearing horizons in the surficial aquifer and the water in the ponds. In addition, no MOGAS-related contaminants were detected in the groundwater samples collected from the artesian wells serving the watercress farms (Ogden 1996a; Earth Tech 2000a).

Evaluation of Potential Public Health Hazards

Water from the surficial aquifer near the site *is not used for human consumption.* This aquifer consists of silty sands and gravels that do not yield large quantities of water and the water produced is high in total dissolved solids. This aquifer not a suitable source of potable water (Ogden 1996a). In addition, the these deposits typically form a barrier preventing the groundwater lying on top of the deposits from migrating to the deeper basal aquifer in the basalt. Because the deposits confine the groundwater in the basal aquifer, the groundwater in that basal aquifer is under progressively greater pressure as it migrates downward to Pearl Harbor. Thus, the groundwater in the basal aquifer would rise to a greater level or elevation if allowed to escape. The springs found near the watercress farms are a natural expression of the confined deep aquifer groundwater escaping upward to the surface. The implication of this upward flow or hydrologic gradient is that any groundwater leakage between the two aquifers would be from the basal aquifer upward toward the surficial aquifer. This suggests that any contamination in the local surficial aquifer could not contaminate the basal aquifer.

From the data and information reviewed*, ATSDR concludes MOGAS-related contaminants from EJFDF have not migrated to the deep freshwater aquifer and have not contaminated the artesian well water supply in the watercress ponds area downgradient from EJFDF. It is also highly unlikely that MOGAS-related contaminants released at EJFDF in 1971, will affect the deep freshwater aquifer in the future.*

Given the hydrogeologic conditions that exist at the EJFDF site*, ATSDR concludes that the MOGAS-related contaminants now found in the sirficial aquifer have not contaminated the watercress ponds and it is also highly unlikely that that those ponds will be contaminated from the EJFDF MOGAS release in the future.*

In the EJFDF area, the surficial aquifer is not used for a potable water supply. Given the hydrogeologic character of these deposits, it is unlikely that thesurficial aquifer will be used as a drinking water source in the future.

For those reasons*, ATSDR concludes that there is not a completed pathway of human exposure to MOGAS-related contaminants from the EJFDF site and that there are no adverse human health effects that have or will result from this MOGAS release*.

Red Hill Oily Waste Disposal Facility

Site Description

Red Hill OWDF is located approximately 2 miles northeast of Pearl Harbor (Figure 12). The OWDF is located within the Red Hill Naval Reservation and is operated by FISC. Red Hill OWDF is a fenced facility and public access is not permitted (Earth Tech 2000b). The storage facilities are located about 3,000 feet east in an adit (a horizontal tunnel) containing 20 large-capacity USTs. Each UST is capable of storing 12.6 million gallons of fuel and is connected to other Navy facilities by pipelines and tunnels (Figure 13). The adit (Adit 3) also contains a drinking water pumping shaft that is located about 700 feet east of the OWDF (Earth Tech 2000b).

The Navy built the OWDF (Figure 14) in the early 1940s, as a collection and disposal facility for the oily wastes generated by cleaning the Red Hill USTs. From sometime in the early 1940s until 1948, oily wastewater and sludge produced from cleaning the USTs was routed to an unlined pit ("former oily waste disposal pit"). Recoverable oil was skimmed off and stored in two 8,000-gallon ASTs and trucked from the site. Beginning in 1949, the oily wastewater was collected in two 8,000-gallon ASTs and then trucked to an off-site disposal facility. Use of the ASTs was discontinued sometime in the early 1970s. Beginning in 1972, the former stilling basin was constructed in about the same area as the site of the former oily waste disposal pit. The stilling basin was originally lined with asphalt, but when cracks developed, it was replaced by a concrete liner in the mid-1970s. The Navy discontinued use of the former stilling basin in 1986, and thereafter, oily wastewater was collected in ASTs.

Access to the OWDF is restricted and there is no evidence of off-site migration of surface soil contaminants. As a result, the community is not directly exposed to soil contaminants from this site.

Remedial Investigations and Actions

Environmental investigations have concentrated on surface and subsurface soils of the stilling basin and other nearby sites of potential concern, sludge in the stilling basin, and groundwater from the underlying perched water table aquifer. The potential air and surface water pathways were also evaluated. Completed remedial actions include removing the former stilling basin, including the basin contents, concrete lining, piping, and surrounding contaminated soil (Ogden 1996a).

Subsurface soil sampling at two OWDF locations (the ASTs and the unauthorized discharge areas) found gas-, diesel-, and lubrication oil–range hydrocarbons migrating toward the groundwater.

Evaluation of Potential Public Health Hazards

Beneath the OWDF, the underlying geology is a complex sequence of interbedded, unconsolidated alluvial deposits (beds of gravels, sands, clays, and mixtures of these sediment types), tuff (consolidated volcanic ash), weathered zones, basalt breccias, and massive basalt flows. The thickness of the unconsolidated deposit is variable, but generally increases across the site from the northeast to the southwest. Groundwater exists in both a perched water table aquifer and a deeper basal aquifer. The perched groundwater is not a current or potential future drinking water source. It is separated from the basal aquifer by a minimum of two confining clay layers (Earth Tech 2000b). At this location the basal aquifer is an artesian aquifer that is partially or completely confined by impermeable beds above it. The groundwater in the basal artesian aquifer is under greater pressure than the groundwater in the overlying rocks. The hydraulic gradient is upward, toward the surface, and any groundwater contaminants found in the perched aquifer beneath the OWDF are prevented from migrating to the basal aquifer. In addition, the flow direction of the groundwater in the basal aquifer is toward the PWC pumping station in Adit 3. Thus, if contaminants released at the OWDF had reached the basal aquifer, they would have been detected in drinking water samples collected from the pumping station.

Very low concentrations of site-related contaminants were detected in the perched groundwater at levels below those known to result in adverse health effects. No site-related contaminants were detected in samples from the basal aquifer or the PWC pumping station (Earth Tech 2000b).

Based on the information reviewed, *ATSDR concludes that past contaminant releases from Red Hill OWDF have not contaminated the basal drinking water aquifer. Remedial actions undertaken at the site and the artesian character of the basal drinking water aquifer indicate that the basal drinking water aquifer will not be contaminated by these releases in the future*.

For these reasons, *ATSDR concludes that there is not a completed groundwater pathway of human exposure to OWDF-related contaminants and that no adverse human health effects have resulted or will result from the release of contaminants at this site.*

Issue 3: Have spills or releases of VOCs or SVOCs resulted in human exposure to airborne contaminants at levels that might result in harmful health effects?

Conclusions

Various dry-cleaning solvents and fuels were stored and used at the Aiea Laundry. In 1996, ATSDR evaluated the effects environmental releases may have had on the ambient and indoor air quality of the nearby, off-site facilities. For this PHA, ATSDR reviewed the new data and information about this site and concluded, as in 1996, that the VOCs released from previous activities at the Aiea Laundry do not pose a past, current, or potential future health hazard for the staff, students, members, or residents of the St. Elizabeth Church and School, neighboring residential area, or Aiea Elementary School.

Aiea Laundry

Site Description

The Aiea Laundry site is located in the Oahu residential community at the northeast corner of Moanalua Road and Kaimakani Street in Aiea, Hawaii. The 4-acre laundry facility is located about 0.3 miles east of East Loch and about 1.1 miles northeast of PHNC (Figure 15). It served as the PHNC laundry beginning in 1942. Dry-cleaning operations were conducted there from the early 1950s until 1998. Various dry-cleaning solvents and fuels have been used during the years of operation and were stored in four USTs. Diesel and reclaimed fuel oil for the laundry boiler was stored in an additional UST. Laundry operations ceased in March 1998.

The laundry site is surrounded by a chain link fence. It is bordered to the north by St. Elizabeth Church and School and a residential area, and to the southeast by Aiea Elementary School (Figure 16). The western portion of the site consisted of the laundry and dry-cleaning building and a boiler house. The eastern portion of the site consisted of an open, grassy area with two storage buildings. The St. Elizabeth Church and School were built sometime between 1962 and 1969, and are within 75 feet of the Aiea Laundry fence. The laundry buildings were demolished and the debris removed in December 1998. All that currently remains at the site are the concrete floor slabs of the laundry building, boiler house, and storage buildings. Asphalt paving covers most of the western portion of the site, around the floor slabs.

In the past, there were concerns that releases of VOCs at the laundry might affect the indoor air quality at the nearby St. Elizabeth Church and School. ATSDR (1996a) reviewed the potential health effects of measured levels of ambient and indoor air at the church facility and determined that there were no public health hazards resulting from the volatile dry-cleaning compounds at the Aiea Laundry.

Remedial Investigations and Actions

Environmental concerns about the site were raised in 1989, when dry-cleaning solvents were detected in two surface soil samples collected in an unlined drainage swale near the northwest property line, near St. Elizabeth Church and School (AMEC 2002). Remedial actions included the removal of five USTs, drain lines and other piping, and some contaminated soil in 1993. Soil sampling following UST removal indicated that solvents, including perchloroethylene (PCE), trichloroethylene (TCE), dichloroethylene (DCE), and vinyl chloride, had been released from the USTs, a floor drain in the laundry facility, and the drain line that discharges to the unlined swale (AMEC 2002).

Groundwater contaminants include a localized plume of diesel fuel “floating” on the groundwater near the laundry boiler room and PCE, diesel, and other contaminants in the surficial aquifer beneath the site (AMEC 2002). Those contaminants, principally chlorinated VOCs, have migrated about 180 feet off site in a southwestward direction towards Aiea Bay on Pearl Harbor. Although this portion of the surficial aquifer is classified as a potential drinking water source, there is no domestic use of this groundwater. However, a removal action was implemented in 1999 to remove on-site, diesel-range organics from the surficial groundwater (AMEC 2002). The groundwater flow direction in this area is away from the Aiea School and the groundwater contaminants are unlikely to affect the potable water at the Aiea School or neighboring residents.

Evaluation of Potential Public Health Hazards

ATSDR evaluated the potential for groundwater contaminants to affect the indoor air quality of St. Elizabeth Church and School. Investigations of soil vapor and ambient air at the Aiea Laundry determined that VOCs in soil gases, principally PCE, could migrate into the St. Elizabeth Church and School (Ogden 1993a). Ambient air and indoor sampling at the church, school, and laundry (Building 436) revealed no immediate adverse human health risk to on-site workers, off-site workers, or off-site residents (Ogden 1993b; AMEC 2002).

ATSDR conducted a site visit to PHNC during January 18–20, 1995, and reviewed the status of investigations at the Aiea Laundry. Following the visit, ATSDR evaluated the levels of PCE and several other VOCs measured in the indoor air at the church and school. The samples reported PCE ranging from 0.00022 to 0.00075 parts per million by volume (ppmv) (Ogden 1993b). ATSDR evaluated the potential health effect of these measured concentrations by constructing a "worst case" scenario for potential human exposure to those dry-cleaning fluids. Potential past exposures were estimated using the maximum levels of VOCs that may have been released from the contaminated soils in the unlined drainage swale near the church buildings.

ATSDR (1996a) concluded that the VOCs released from previous activities at the Aiea Laundry did not pose a current health hazard for the church staff, students, and members. Further, ATSDR concluded that past exposures did not pose a health hazard and future exposures, at levels of health concern, are not likely to occur. ATSDR concurred with the Navy's conclusion that the indoor air of the St. Elizabeth Church and School and the ambient air near the Aiea Laundry do not pose a health hazard now or in the past.

To ensure that the release of soil gases to the environment do not pose a future health hazard, a soil vapor extraction (SVE) system was put into service. This SVE system was designed to prevent soil vapor migration and to remove the remaining subsurface VOCs (AMEC 2002). In a follow-up action, in June 2000, the Navy conducted a soil vapor survey at the St. Elizabeth Church and School (AMEC 2002). PCE was detected in only one sample on the church property, at a level of 0.13 ppmv at a depth of 7.5 feet. No potential for current or future human exposure to PCE or other contaminants previously released at the Aiea Laundry was identified.

From the available data and information, *ATSDR concludes now, as in 1996, that the VOCs released from previous activities at the Aiea Laundry do not pose a past, current, or potential future health hazard for the church staff, students, and members.*

Issue 4: Are fish and crabs collected from Pearl Harbor safe to eat?

Conclusion

It would be a prudent public health practice to limit consumption of fish and crabs from Pearl Harbor, due to the level of PCBs detected. ATSDR supports the HDOH's advisory to avoid eating fish and shellfish from Pearl Harbor due to the level of PCBs detected.

Site Description

Pearl Harbor is a natural, high-nutrient estuary composed of three main lochs (West Loch, Middle Loch, and East Loch) with a single channel entrance. It encompasses about 5 square miles of water surface area (NAVFAC 2004). The harbor receives freshwater from five perennial streams (Halawa, Kalauao, Waiawa, Waikele, and Waimalu), three ephemeral streams (Aiea, Honouliuli, and Waiau), artesian springs, and shallow aquifers (DOI 1969). The total drainage area for Pearl Harbor is about 110 square miles (285 square kilometers, or about 20 percent of Oahu's land surface) and encompasses seven watersheds (NAVFAC 2004). An estimated 50–100 million gallons of freshwater enter the harbor every day (Grovhoug 1992).

Pearl Harbor is under the jurisdiction of the Navy (the Navy controls all harbor waters and most of the shoreline). Before September 11, 2001, the Navy had a liberal access policy that allowed commercial and recreational vessels to enter the harbor (Grovhoug 1992). Since that date, only ships from U.S. federal agencies and transient ships of friendly foreign navies are allowed access (P. Nakamura, personal communication, April 5, 2005). The land under Navy control is primarily operational and industrial activities; unaccompanied personnel housing; and administrative, training, and support facilities. The land in private and public areas shifted from agricultural to primarily commercial, industrial, and residential (Grovhoug 1992).

The Hawaiian anchovy (nehu, *Encrasicholina purpurea*) is used as a baitfish for offshore tuna (aku). The upper regions of the Pearl Harbor lochs provide ideal habitat for this important resource. Before September 11, 2001, insured, commercial tuna boats were allowed to collect anchovies from certain regions of Pearl Harbor (Grovhoug 1992). Since that date, commercial fishing in the harbor is not allowed (P. Nakamura, personal communication, April 5, 2005). Fish and wildlife resources at PHNC are managed through a cooperative agreement with the Navy, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Hawaii State Department of Land and Natural Resources (Ogden 1996b). Until the 1890s, several walled fishponds inside Pearl Harbor were used to cultivate a variety of edible fish and seaweed (Grovhoug 1992).

In 1998, the HDOH issued a fish advisory for Pearl Harbor, as a precautionary measure in response to fish and crab samples collected by the Navy. (A fact sheet of the advisory is provided in Appendix C.) Consequently, signs were posted in known fishing areas that advise people not to eat fish or shellfish from the harbor. Before the advisory, people would collect and eat fish, shellfish, and algae from Pearl Harbor (Grovhoug 1992; Ogden 1996b). While fishing is not prohibited in Pearl Harbor, signs are posted around the area so that people have the opportunity to observe and heed the advisory.

Sources of Environmental Contamination

Siltation is the primary process of contamination in Pearl Harbor. About 96,000 tons of sediment are transported into the harbor each year through natural watershed ecosystem processes (Grovhoug 1992). Because individual sediment particles have large surface areas, molecules of chemicals easily attach to them and are then transported along with the sediment (NAVFAC 2004). Both natural and manmade contaminants are transported into Pearl Harbor through this process.

- Metals are naturally occurring in the volcanic soils of Hawaii. Copper, zinc, nickel, and chromium are found naturally in higher concentrations in Hawaiian soils than the mainland. Therefore, Pearl Harbor receives a substantial amount of metal contamination because it serves as a natural trap for sediment particles (NAVFAC 2004).

- Petroleum-based hydrocarbons (i.e., fuels) are released into Pearl Harbor through civilian and Navy spills, releases from the USS Arizona, and nonpoint sources, such as underground pipes and vessel bilge water (Grovhoug 1992).

- Pesticides, such as DDT and chlordane, were used as insecticides in the past. They are transported to Pearl Harbor in surface water runoff from agricultural areas of the watershed (Grovhoug 1992; NAVFAC 2004).

- PCBs are found in the dielectric fluid of capacitors and transformers. Several transformer accidents occurring in the naval shipyard region contributed to the PCB contamination found in Pearl Harbor (Grovhoug 1992; NAVFAC 2004).

- Chemicals are slowly released into Pearl Harbor from the antifouling coatings that are used on ship hulls to prevent the growth of marine organisms (Grovhoug 1992).

- While there is no specific study to document the presence of ordnance in Pearl Harbor, the Navy estimates that the probability for serious ordnance contamination is low (Grovhoug 1992).

- Bacteria and other microorganisms enter Pearl Harbor through streams and sewage effluent discharges. Severe coliform bacterial contamination has caused considerable damage to much of the resident eastern oyster population (Grovhoug 1992).

- Detailed surveys showed that no substantial radiological contamination was present in water, sediment, or tissue samples from Pearl Harbor (EPA 1987; M&E Pacific 1983).

Because of the large amount of sediment deposited in the harbor each year, maintenance dredging is required every 4 to 5 years (Grovhoug 1992). This dredging partially lessens the effects of the sediment contamination by periodically removing the upper layers of sediments (Navy 1983).

Nature and Extent of Environmental Contamination

> It is standard protocol to analyze the whole body of organisms when evaluating ecological concerns and fillets/edible portions when evaluating human health concerns.

In 1996, the Navy collected tissue samples from 15 fish fillets (6 tilapia [*Oreochromis mossambicus*], 5 bandtail goatfish [*Upeneus taeniopterus*], and 4 mullet [species not specified]), 15 whole fish (8 tilapia and 7 goatfish), and 15 blue-clawed stone crabs (*Thalamita crenata*) during the Pearl Harbor Sediment Study (see Ogden 1996b, NAVFAC 2004, and NAVFAC 2005 for details). These species were chosen for the following reasons:

1. They are bottom feeders that are more exposed to contaminated sediments.
2. They are readily available throughout the harbor.
3. They are commonly caught and consumed by the public.

Samples were taken from five locations within each loch—West Loch, Middle Loch, and East Loch—in areas where people were frequently observed fishing and crabbing (see Figure 17; Navy 1998). The whole fish and whole crab samples were analyzed for 276 chemicals—including metals, butyltins, polycyclic aromatic hydrocarbons, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, and ordnance-related compounds. The fish fillet samples were analyzed for a subset of these—metals, chlorinated pesticides, dioxins/furans, and PCBs. However, many of the additional chemicals sampled in the whole fish and whole crab samples were not detected.

How do contaminants get in fish?

Contaminants such as PCBs settle to the bottom of a river and collect in sediment. PCBs do not easily decompose and will remain in the environment for many years. Fish take in PCBs when they eat sediment or smaller fish containing PCBs. In this way, larger and older fish can build up high levels of contaminants.

HDOH and EPA toxicologists reviewed the data and suggested an advisory be issued stating that marine life from Pearl Harbor should not be eaten (Navy 1998). The Navy performed a preliminary human health risk screening analysis and is conducting a human health risk assessment. Preliminary results indicate eating more than one-half meal of whole fish or crab from Pearl Harbor a month, or one meal of fish fillets a month, could present an “unacceptable risk” for adults and children (Navy 1998).

Evaluation of Potential Public Health Hazards

ATSDR evaluated the potential health concerns associated with eating fish and crabs from Pearl Harbor. Adults were assumed to eat 2.5 fish meals a week and three crab meals a month. Children were assumed to eat two fish meals a week and two crab meals a month. ATSDR further assumed that preparation methods did not alter the chemical concentration in the fish tissue. However, preparation methods can significantly reduce the exposure to certain chemicals. Cooking fish can remove approximately 20–30 percent of the PCBs (Sherer and Price 1993).

For most chemicals identified in the fish, this consumption pattern was not associated with health concerns. However, the estimated PCB exposure *approached* levels in which harmful health effects were observed in animals. (See Appendix B for details of the evaluation). ATSDR also considered EPA’s risk-based consumption limits for the general adult population (EPA 2000) to determine the maximum number of fish meals per month that can be safely eaten in light of measured chemical concentrations. This method also indicates it would be prudent to limit the amount of fish eaten from Pearl Harbor due to the levels of PCBs detected in the fish fillets.

Both of these evaluation methods indicate it would be prudent public health practice to limit consumption of fish and crabs from Pearl Harbor. Certain sensitive populations, such as pregnant women and children, should be particularly careful to avoid eating fish or crabs from Pearl Harbor, because exposure to PCBs can cause developmental problems. *ATSDR supports the HDOH fishing advisory and encourages people to heed the posted sign and not eat fish caught in Pearl Harbor.*

Issue 5: Can incidental, environmental exposure to Pearl Harbor sediments result in harmful health effects?

Conclusion

Incidental exposure to Pearl Harbor sediments is *not* expected to result in harmful health effects. ATSDR evaluated the potential risks from daily exposure to the sediment and concluded that none of the chemicals were detected in high enough concentrations to be a health concern.

Site Description

See Issue 4 (Are fish and crabs collected from Pearl Harbor safe to eat?) for a description of the Pearl Harbor estuary and the sources of environmental contamination.

Nature and Extent of Environmental Contamination

In 1996, 219 sediment samples were collected throughout Pearl Harbor (including the West Loch, Middle Loch, East Loch, Southeast Loch, and Navigation Channel) during the Pearl Harbor Sediment Study (see Ogden 1996b, NAVFAC 2004, and NAVFAC 2005 for details). Thirty-eight of the sediment samples were co-located with the 15 known fishing and crabbing locations. The samples were analyzed for 276 chemicals—including metals, butyltins, polycyclic aromatic hydrocarbons, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, and ordnance-related compounds. Most of the SVOCs, many of the pesticides, and all of the ordnance-related compounds were either not detected or detected infrequently (i.e., in less than 10 percent of the samples) in the sediments.

Evaluation of Potential Public Health Hazards

ATSDR evaluated whether incidentally ingesting sediments from Pearl Harbor every day for a lifetime would result in harmful health effects. The concentrations that were present throughout Pearl Harbor were too low to be of health concern for anyone incidentally ingesting Pearl Harbor sediments. Please see Appendix B for more details concerning ATSDR's evaluation.

Child Health Considerations

ATSDR recognizes that infants and children may be more sensitive to exposures than adults in communities with contamination in water, soil, air, or food. This sensitivity is the result of several factors. Children are more likely to be exposed because they play outdoors and they sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than adults, which mean they breathe dust, soil, and heavy vapors close to the ground. Children are also smaller, potentially resulting in higher doses of chemical exposure per unit body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care. Therefore, ATSDR is committed to evaluating their special interests at sites such as PHNC.

Like other people living or working at or near PHNC, children may contact contaminated site media, as discussed in the "Evaluation of Public Health Issues and Concerns" section of this PHA. To evaluate whether children may experience adverse health effects through past, current, or future exposures to site contaminants, ATSDR estimated potential doses specifically for children. To estimate these doses, ATSDR used very conservative assumptions that overestimate the levels of actual exposure. Specifically, ATSDR evaluated potential childhood exposures to

- surface soil contamination at the former sites of the PCPLF, WALF, the Waipio Peninsula pesticide mixing facility, and Transformer W-11 on Waipio Peninsula;
- past indoor air contamination at the St. Elizabeth Church and School adjacent to the former PHNC Aiea Laundry Facility;
- contaminants in fish and crabs collected from Pearl Harbor; and
- contaminants found in Pearl Harbor sediments.

ATSDR determined that limited past, present, or potential future incidental exposure to contaminants found in the surface soils of the sites evaluated or Pearl Harbor sediments do not pose health hazards for children. Similarly, ATSDR determined that exposure to low levels of indoor air contamination found in the past at the St. Elizabeth Church and School were not of health concern for children. However, *ATSDR concluded that children and pregnant women should avoid consumption of Pearl Harbor fish and crabs* because of the levels of PCBs found in the samples collected. As a prudent public health practice, ATSDR also recommends that everyone follow the HDOH's fish advisory.

Conclusions

Based on the evaluation of available environmental information, ATSDR concludes that potential exposure to PHNC-related contaminants pose *no apparent public health hazard*. *However, ATSDR encourages local residents to follow the established Hawaii Department of Health advisory to not eat fish or crabs from Pearl Harbor.* Conclusions regarding media- and site-specific exposures are as follows:

Potential Exposure to Contaminants in Surface Soils

Pearl City Peninsula Landfill

- From the information reviewed and the remediation actions completed, ATSDR concludes that exposure to the ash deposits in the burn disposal area of the Pearl City Peninsula landfill did not in the past, and do not now, pose a human health threat. Similarly, ATSDR concludes that exposure to the black sand deposits at the landfill, before completion of remediation activities, did not pose a human health threat. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Waipahu Ash Landfill

- From its evaluation of available data, ATSDR concludes that no adverse health effects would result from the short-duration exposures to contaminated surface soils in the Waipahu ash landfill perimeter. ATSDR classified this site as posing *no apparent public health hazard*.

- Because of the anticipated excavation and consolidation of the perimeter surface soils beneath a new landfill cap, ATSDR concludes that the perimeter soils of the Waipahu ash landfill will not pose a potential health threat in the future. The completion of a properly designed landfill cap should ensure the future safety of the recreational users of the planned soccer park in this area. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Former Pesticide Mixing Area, Waipio Peninsula

- ATSDR concludes that incidental exposures to the contaminants at the former pesticide mixing plant are not a past, present, or potential future health threat for trespassers. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Transformer W-11, Waipio Peninsula

- From the information reviewed, ATSDR concludes that incidental exposure to polychlorinated biphenyls (PCBs) in surface soils near the W-11 transformer did not pose a health threat in the past, and because the site has now been remediated, the site does not pose a current or future health threat. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing a *no apparent public health hazard*.

Potential Contamination of Drinking Water Supplies

Ewa Junction Fuel Drumming Facility (EJFDF)

- From the information reviewed, ATSDR concludes that motor gasoline (MOGAS)-related contaminants from EJFDF have not migrated to the basal freshwater aquifer and have not contaminated the artesian well water supply in the watercress ponds area downgradient from EJFDF. Further, it is highly unlikely that MOGAS-related contaminants released at EJFDF in 1971, will affect the basal freshwater aquifer in the future.

- Given the hydrogeologic conditions that exist at the EJFDF site, ATSDR concludes that the MOGAS-related contaminants now found in thesurficial aquifer have not resulted in contamination of the watercress ponds, and it is also highly unlikely that those ponds will be contaminated from the EJFDF MOGAS release in the future.

- The surficial aquifer is not used as a potable water supply in the EJFDF area and, given the hydrogeologic character of the deposits, it is unlikely that the surficial aquifer will be used as a drinking water source in the future.

- ATSDR concludes that there is not a completed pathway of human exposure to MOGAS-related contaminants from the EJFDF site, and that adverse human health effects have not occurred as a result of this MOGAS release and are unlikely to occur in the future. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Red Hill Oily Waste Disposal Facility (OWDF)

- From the information reviewed, ATSDR concludes that past contaminant releases from Red Hill OWDF have not contaminated the basal drinking water aquifer. Remedial actions undertaken at the site and the artesian character of the basal drinking water aquifer ensure that the aquifer will not be contaminated by releases from the OWDF in the future.

- ATSDR concludes that there is not a completed groundwater pathway of human exposure to OWDF-related contaminants, and that no adverse human health effects have resulted or will result from the release of contaminants at this site. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Potential Exposure to Airborne Contaminants

Aiea Laundry

- ATSDR concludes, as in 1996, that the volatile organic compounds released from previous activities at the Aiea Laundry do not pose a past, current, or potential future health hazard for the staff, students, members, or residents of the St. Elizabeth Church and School, the neighboring residential area, or Aiea Elementary School. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard*.

Consumption of Fish and Crabs Collected from Pearl Harbor

- ATSDR supports the Hawaii Department of Health (HDOH) advisory to not eat fish or crab from Pearl Harbor (Appendix C) to prevent possible health effects from long-term exposure to PCBs. ATSDR's evaluation concludes that it is prudent and protective for people to follow this advisory due to the presence of environmental contaminants measured in fish tissue. People who follow the published HDOH fish advisory will not be exposed to these contaminants. ATSDR classified this site as posing *no apparent public health hazard* for people who follow the posted advisory.

Exposure to Pearl Harbor Sediments

- ATSDR concludes that incidental exposure to Pearl Harbor sediments is not expected to result in harmful health effects. Due to the presence of environmental contamination without an identified exposure pathway that would be expected to cause health concerns, ATSDR classified this site as posing *no apparent public health hazard.*

Recommendations

As a prudent public health action, ATSDR recommends that people follow the Hawaii Department of Health advisory to avoid eating fish and crab from Pearl Harbor.

Public Health Action Plan

The Public Health Action Plan for PHNC describes actions taken and to be taken by the Navy, EPA, HDOH, the City and County of Honolulu, and ATSDR in response to the findings of this PHA. Such actions are designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, ongoing, and planned are listed below.

Completed Actions

- The Navy, in cooperation with EPA and HDOH, has completed numerous environmental investigations to identify and characterize releases of environmental contaminants at PHNC and its outlying sites. Removal actions and site remediation have also been completed or partially completed at several sites. Additional sites in need of further evaluation or corrective actions have been identified.

- The City and County of Honolulu, in coordination with the Navy, EPA, and HDOH, conducted or cooperated with the investigation and remediation of formerly used sites located adjacent to or within PHNC.

- The Hawaii Department of Health issued a fish advisory recommending people to not eat fish or crab from Pearl Harbor.

- The Oahu Sugar Company, in cooperation with the Navy and HDOH, has completed an interim environmental investigation to characterize the distribution and level of contaminant releases at the former pesticide mixing plant on the Waipio Peninsula.

- ATSDR has conducted three site visits and completed two public health consultations and this public health assessment, all evaluating contaminant releases at PHNC.

Ongoing Actions

- The Navy and other parties identified above continue to participate in the identification, evaluation, and remediation of sites affected by the release of environmental contaminants at PHNC. The Navy continues to conduct human health and ecological risk assessments to further understand the effects of that contamination.

Planned Actions

- The Navy has identified additional investigation and remediation activities that need to occur at sites previously identified for further action(s).

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Figures

Figure 1. Location Map, Pearl Harbor Naval Complex (PHNC), Oahu, Hawaii

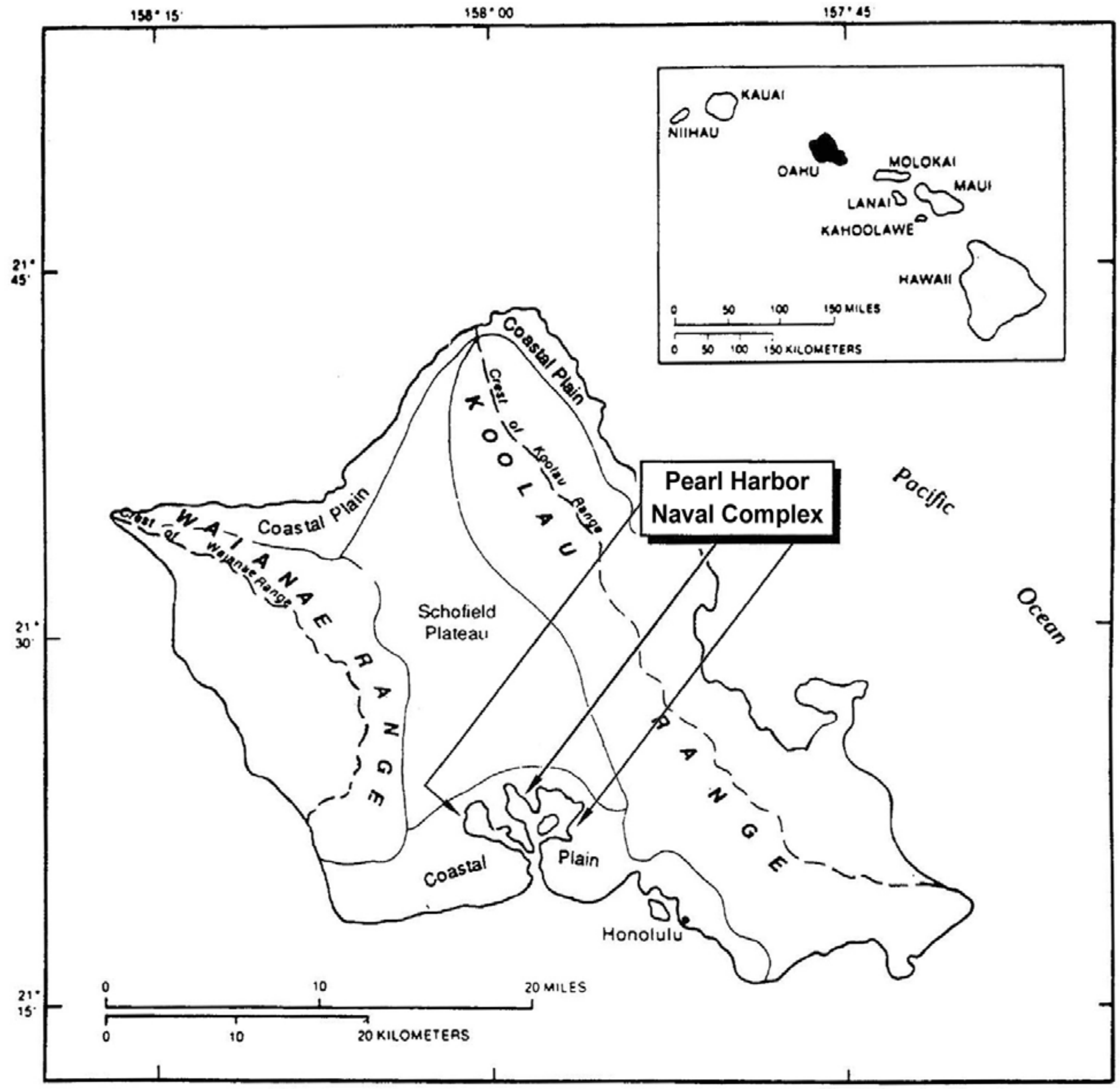


Figure 2. Pearl Harbor Lochs and the Geographic Study Area

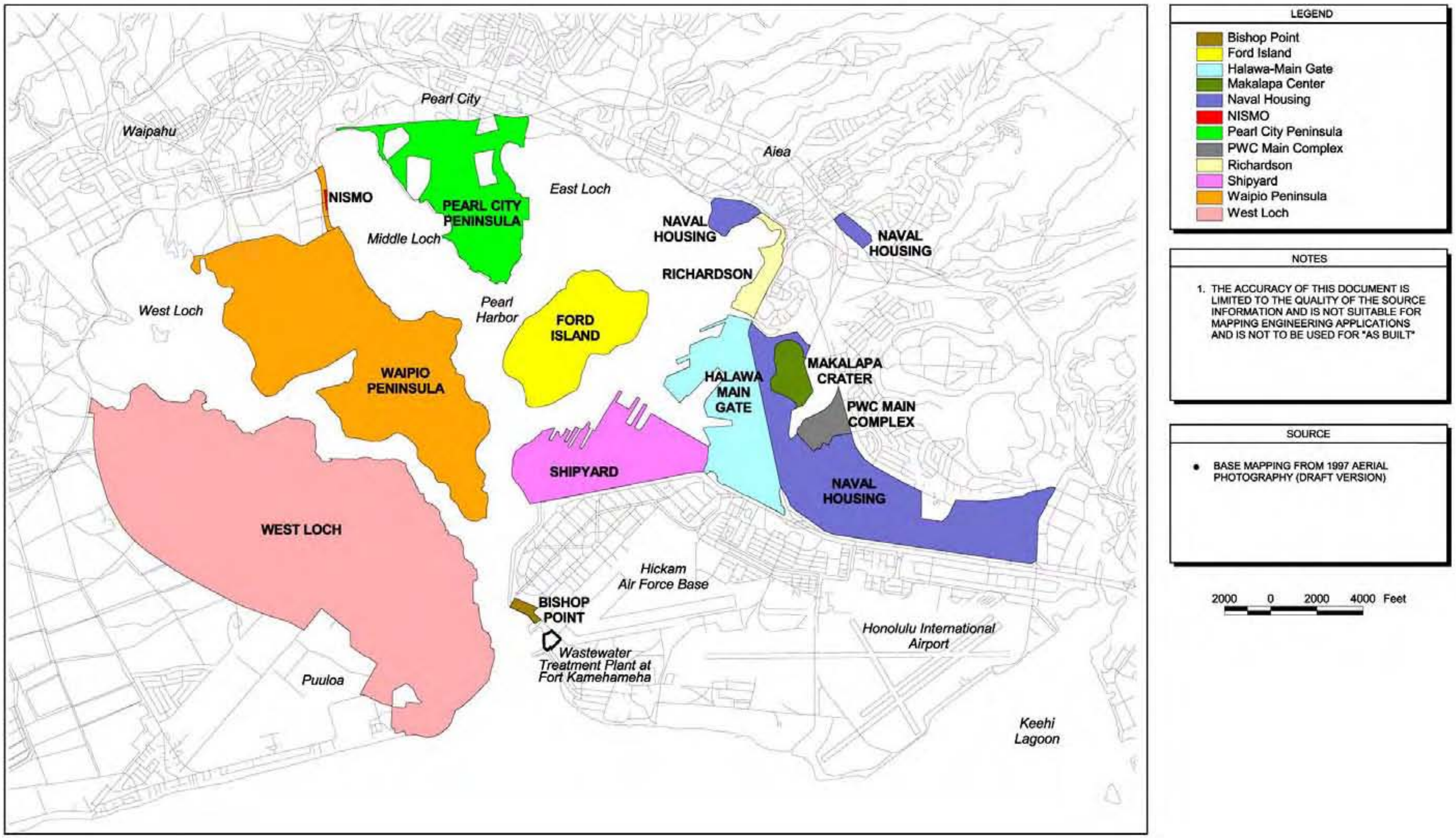


Figure 3. Geologic Features of Oahu, Hawaii

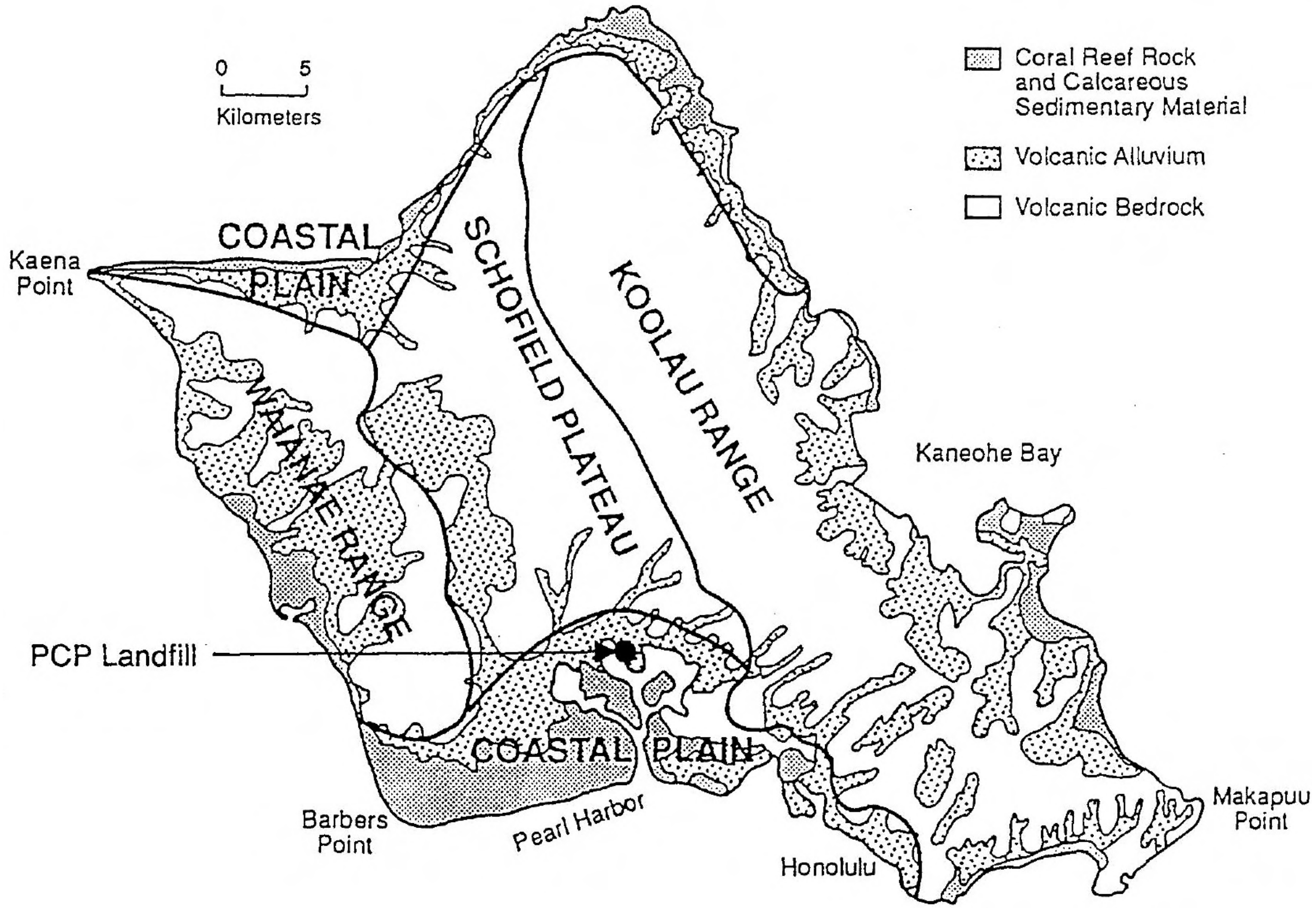


Figure 4. Generalized Hydrogeology of Oahu, Hawaii

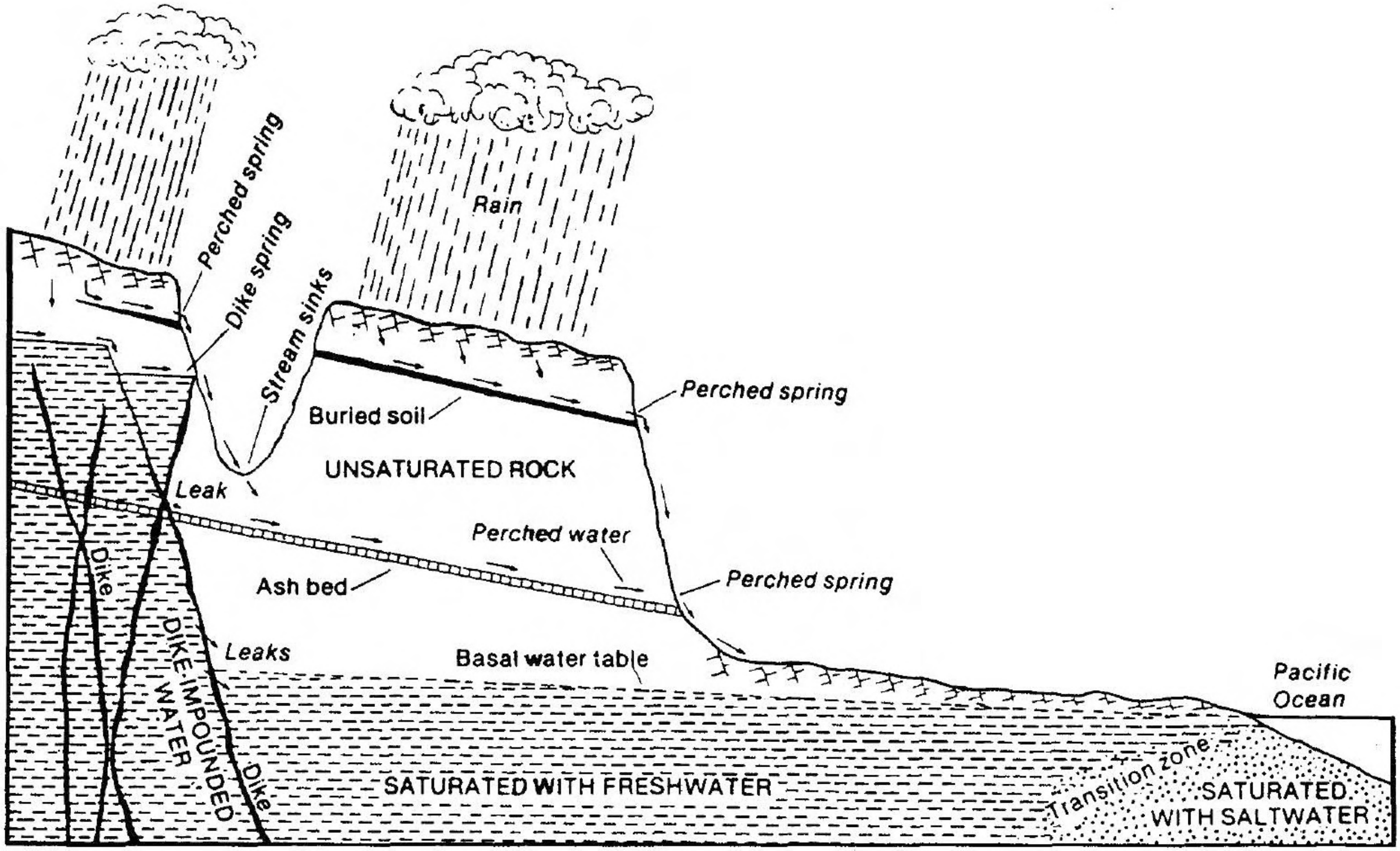


Figure 5. Demographic Within 1 Mile of the Pearl Harbor Naval Complex

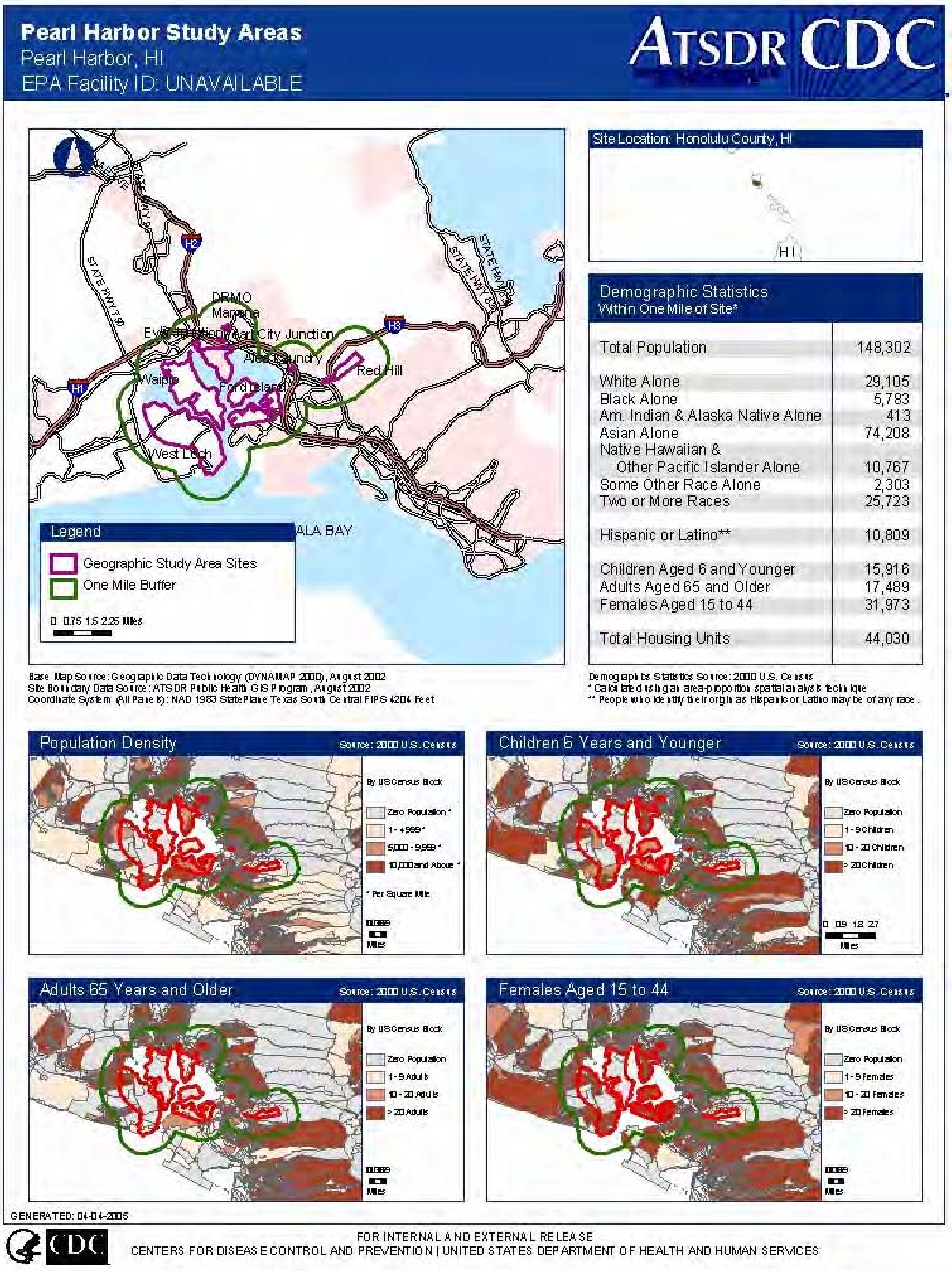
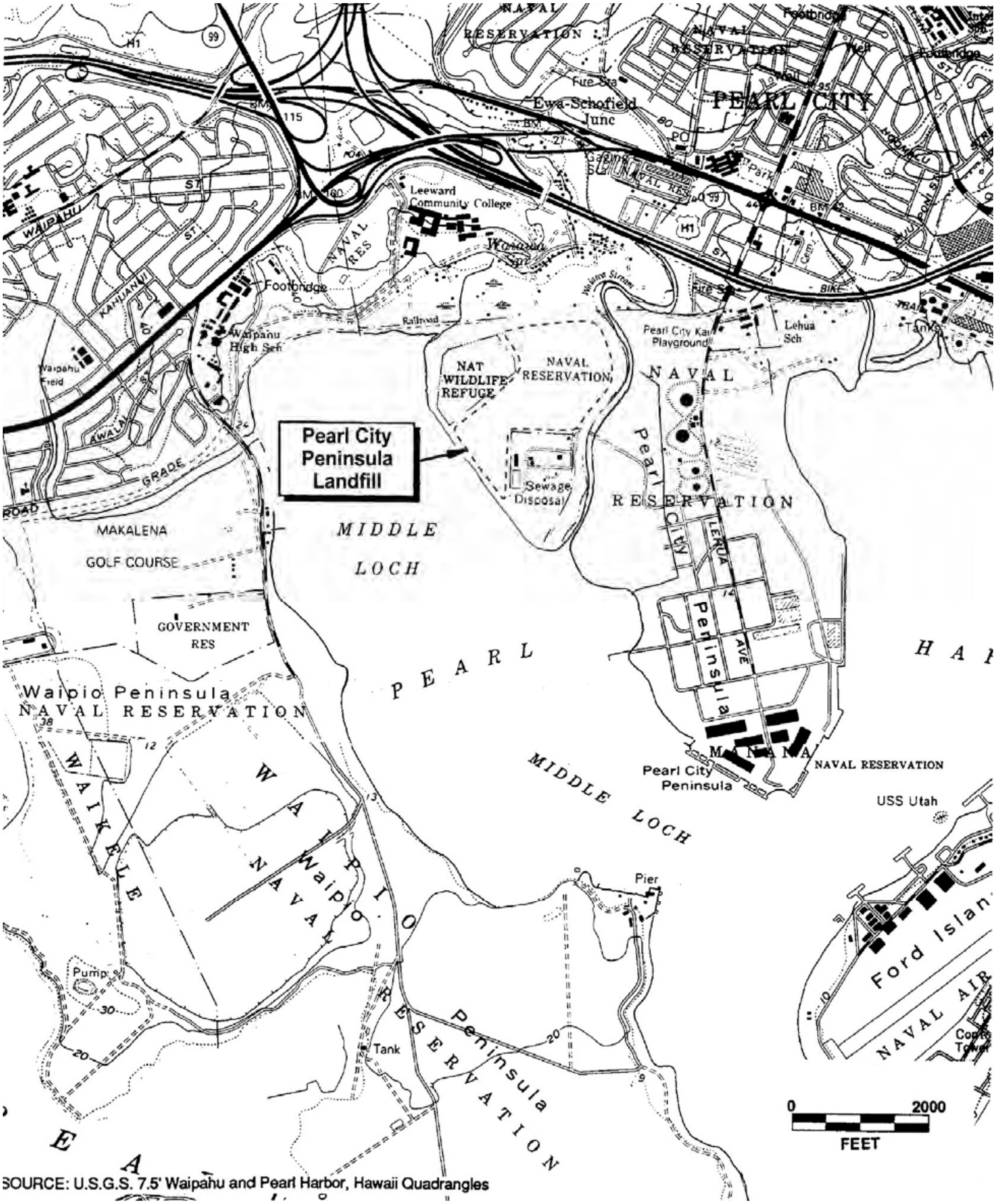


Figure 6. Location Map, Pearl City Peninsula Landfill



SOURCE: U.S.G.S. 7.5' Waipahu and Pearl Harbor, Hawaii Quadrangles

Figure 7. Pearl City Peninsula Landfill, Site Details

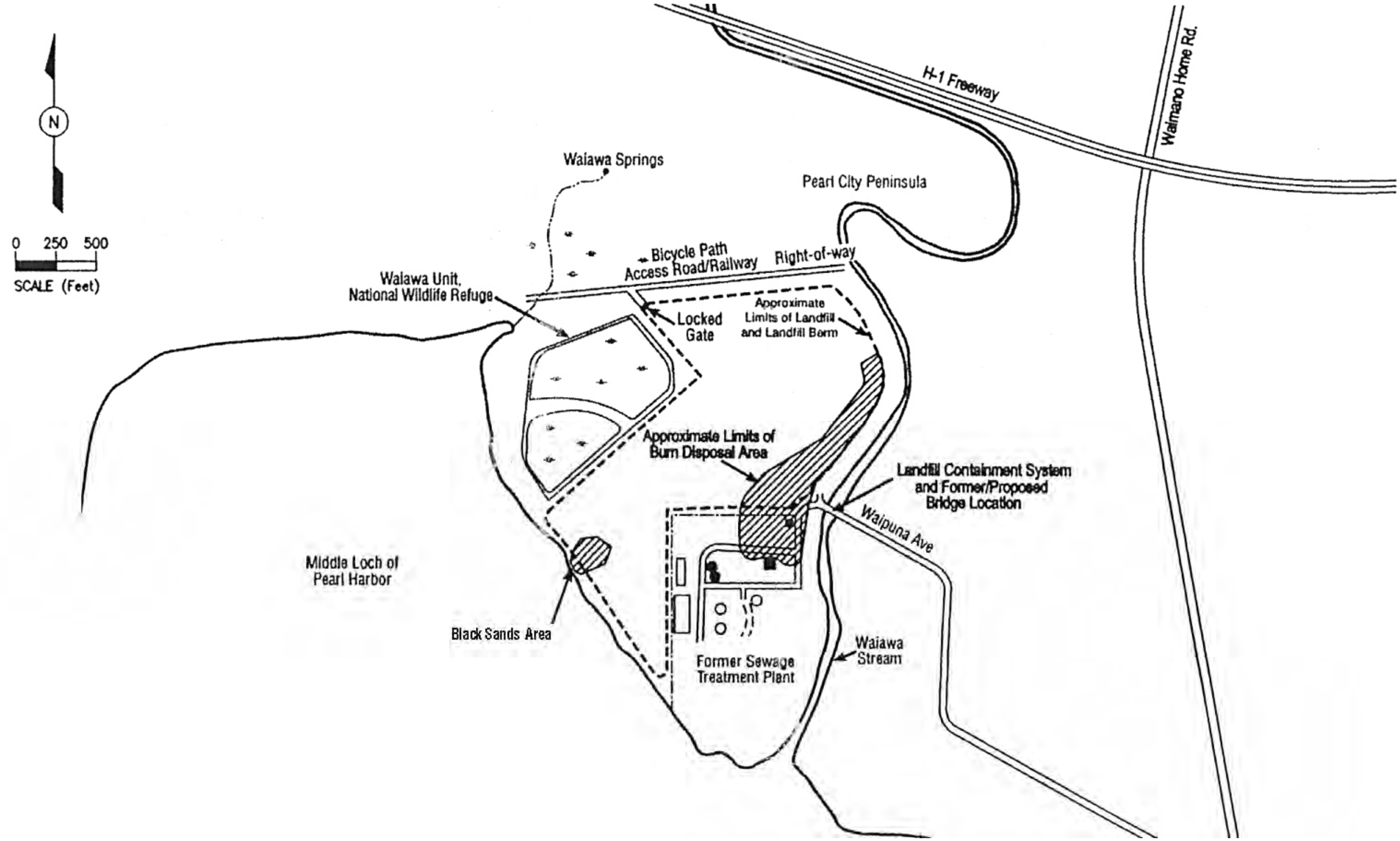


Figure 8. Location Map, Waipahu Ash Landfill

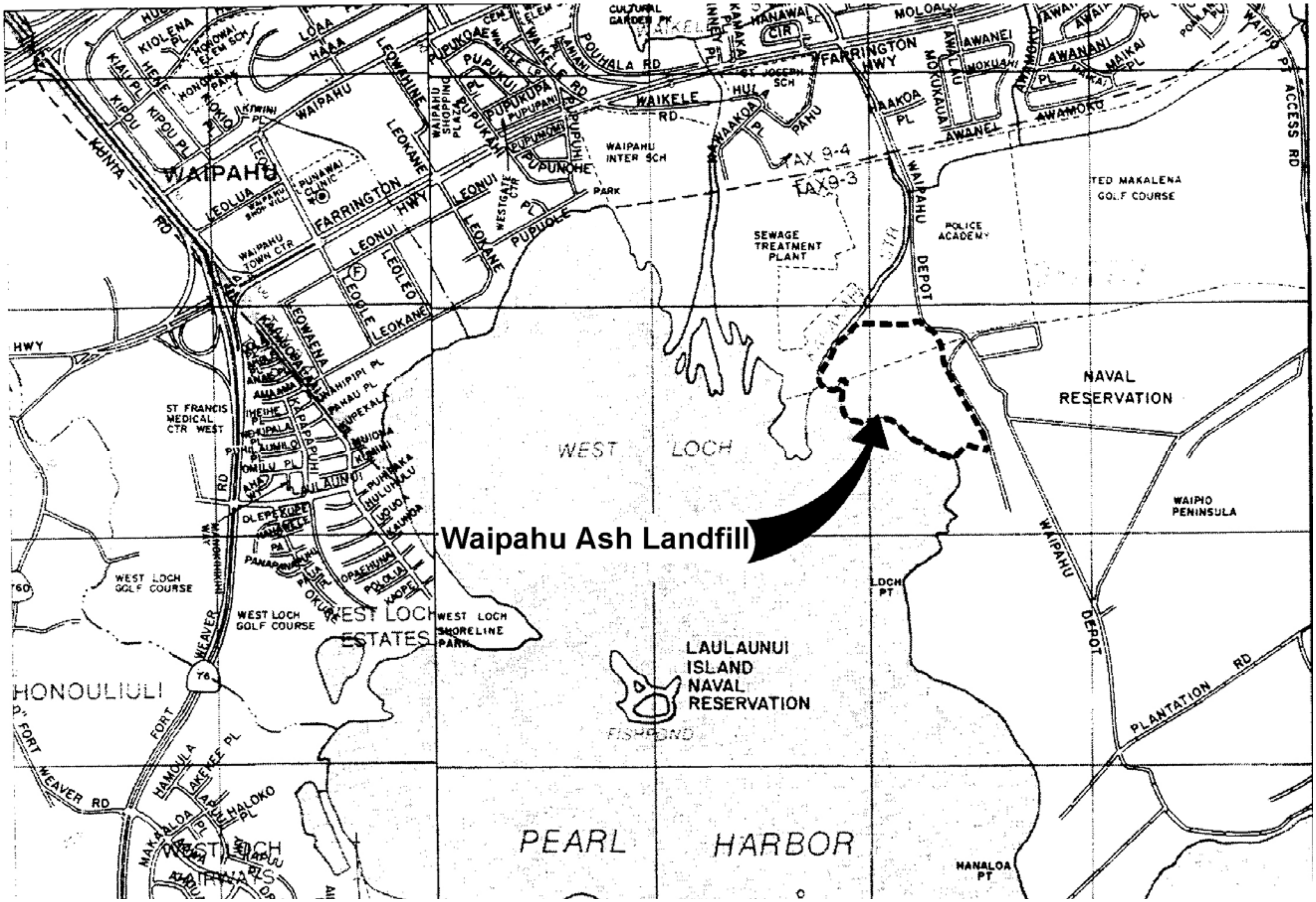


Figure 9. Former Pesticide Mixing Plant, Waipio Peninsula

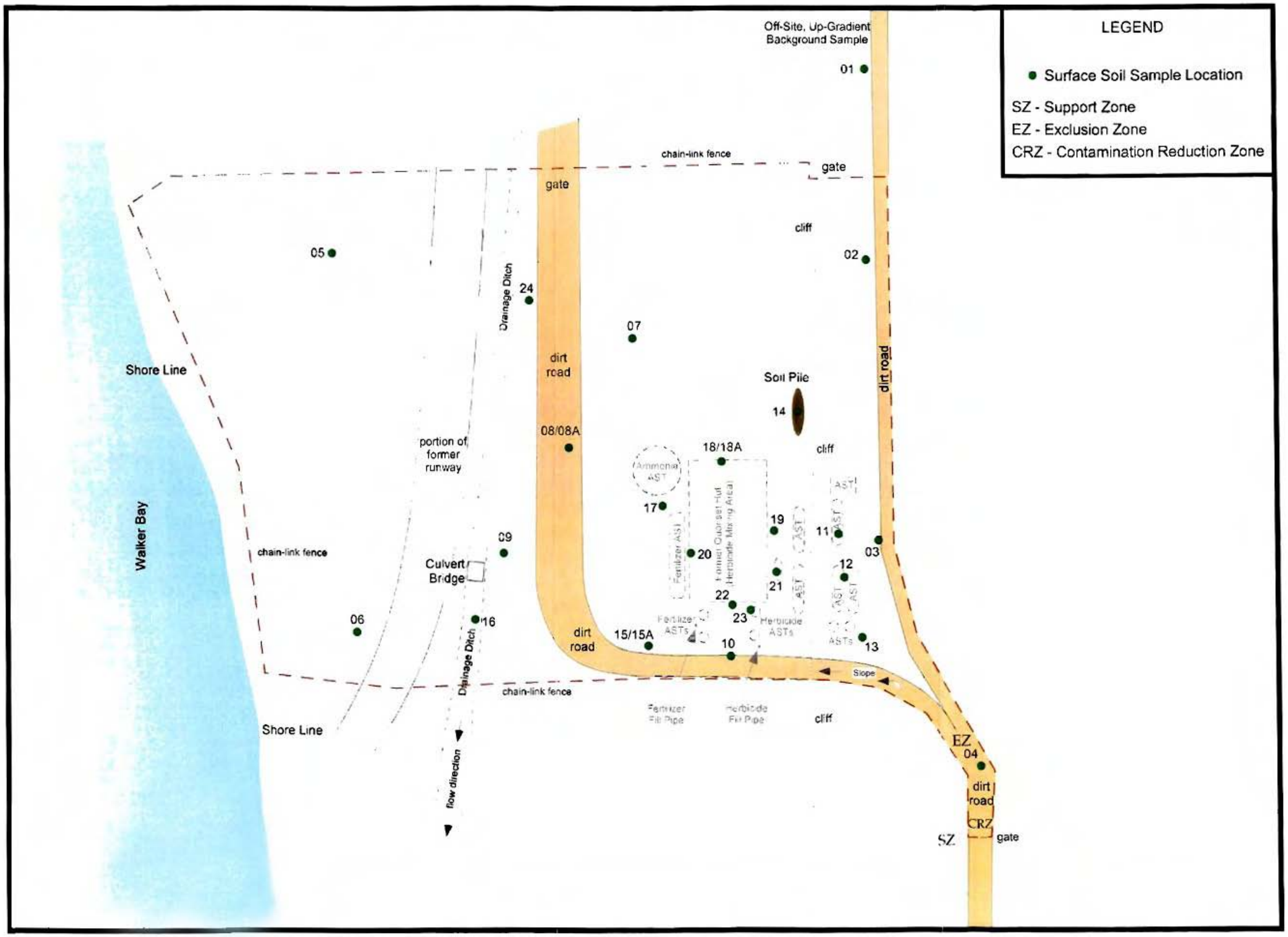


Figure 10. Location Map, Ewa Junction Fuel Drumming Facility (EJFDF)

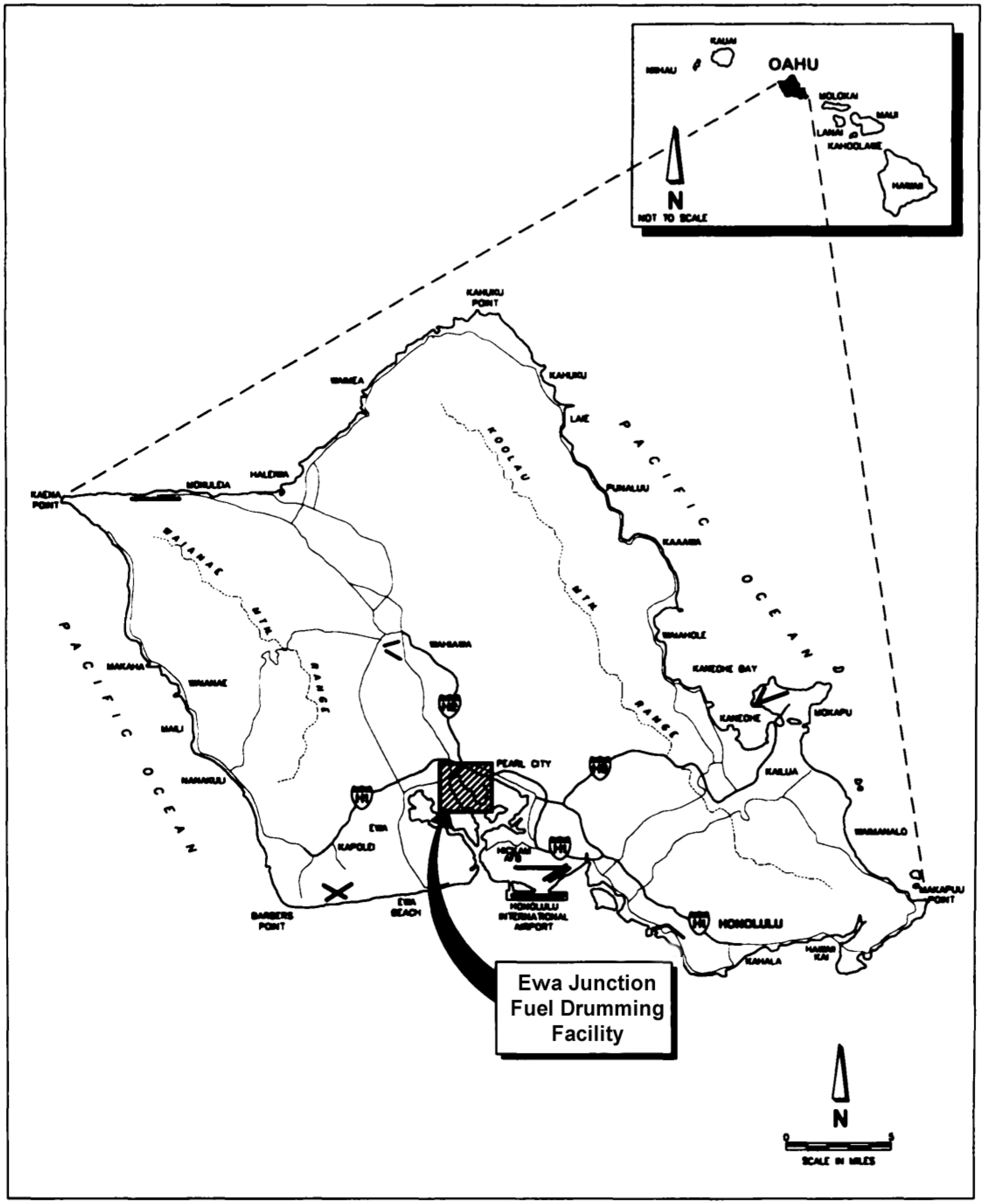


Figure 11. Ewa Junction Fuel Drumming Facility, Site Details

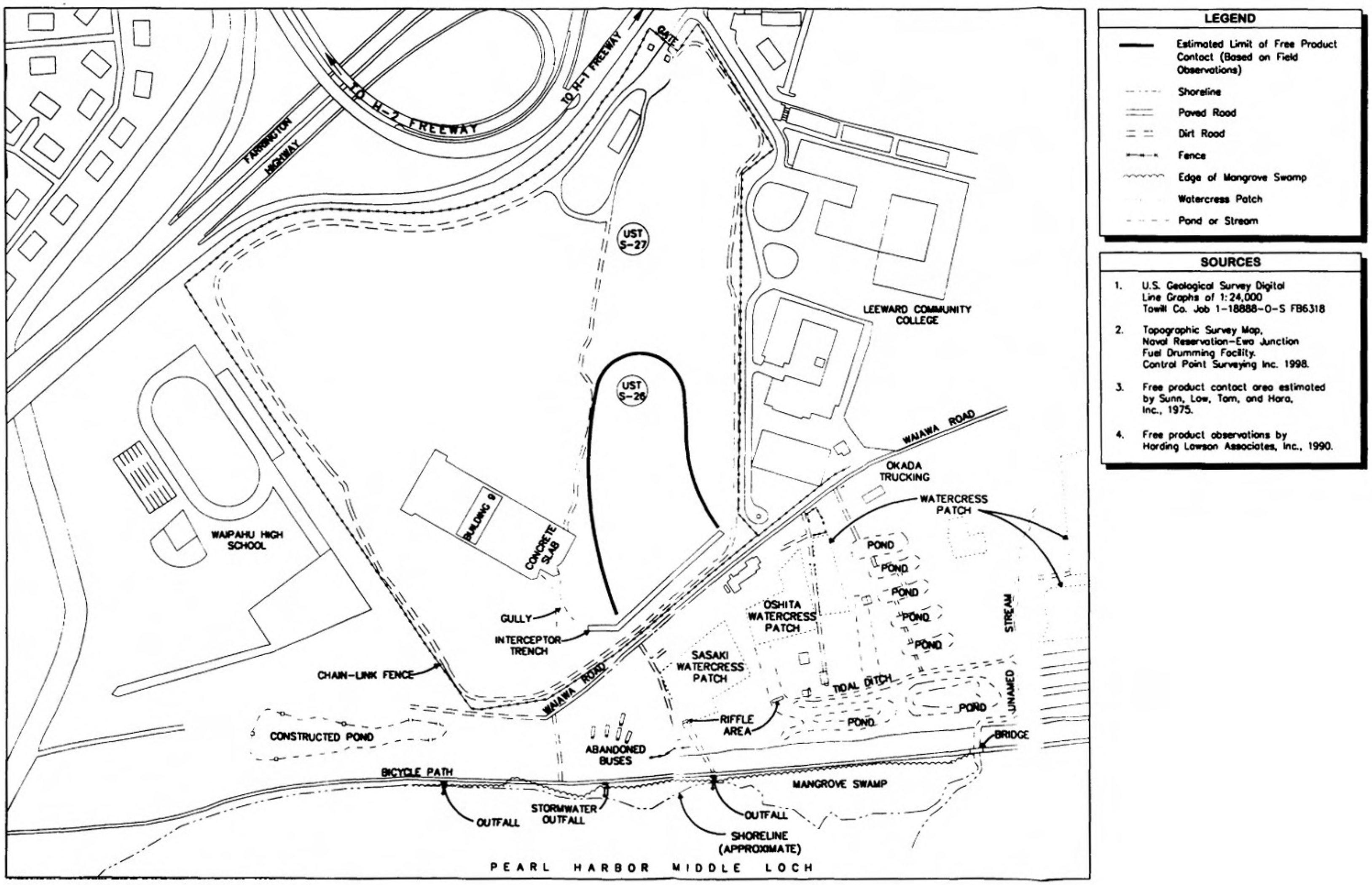


Figure 12. Location Map, Red Hill Oily Waste Disposal Facility (OWDF)

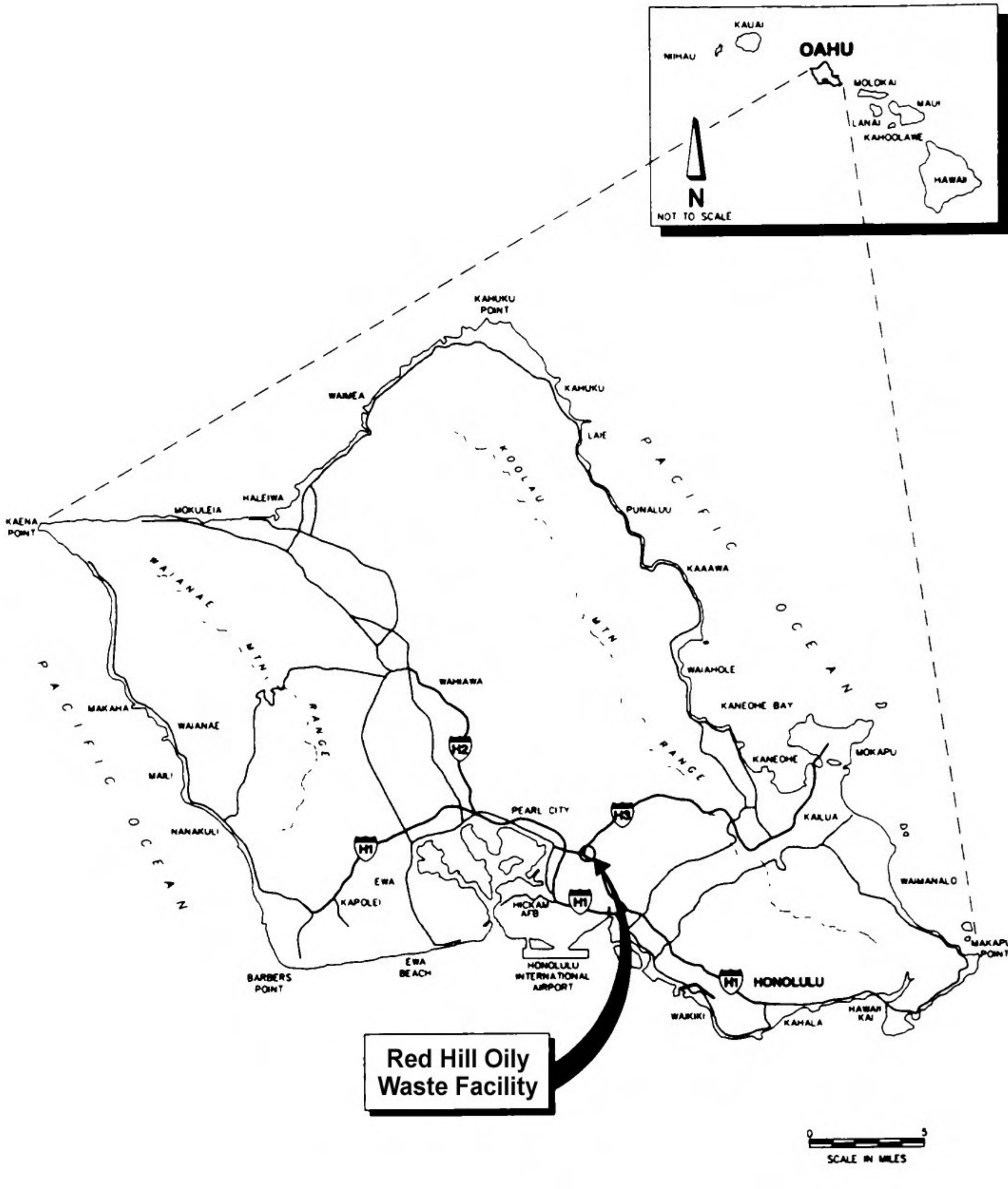


Figure 13. Underground Storage Tanks in Adit 3, Red Hill Oily Waste Disposal Facility (OWDF)

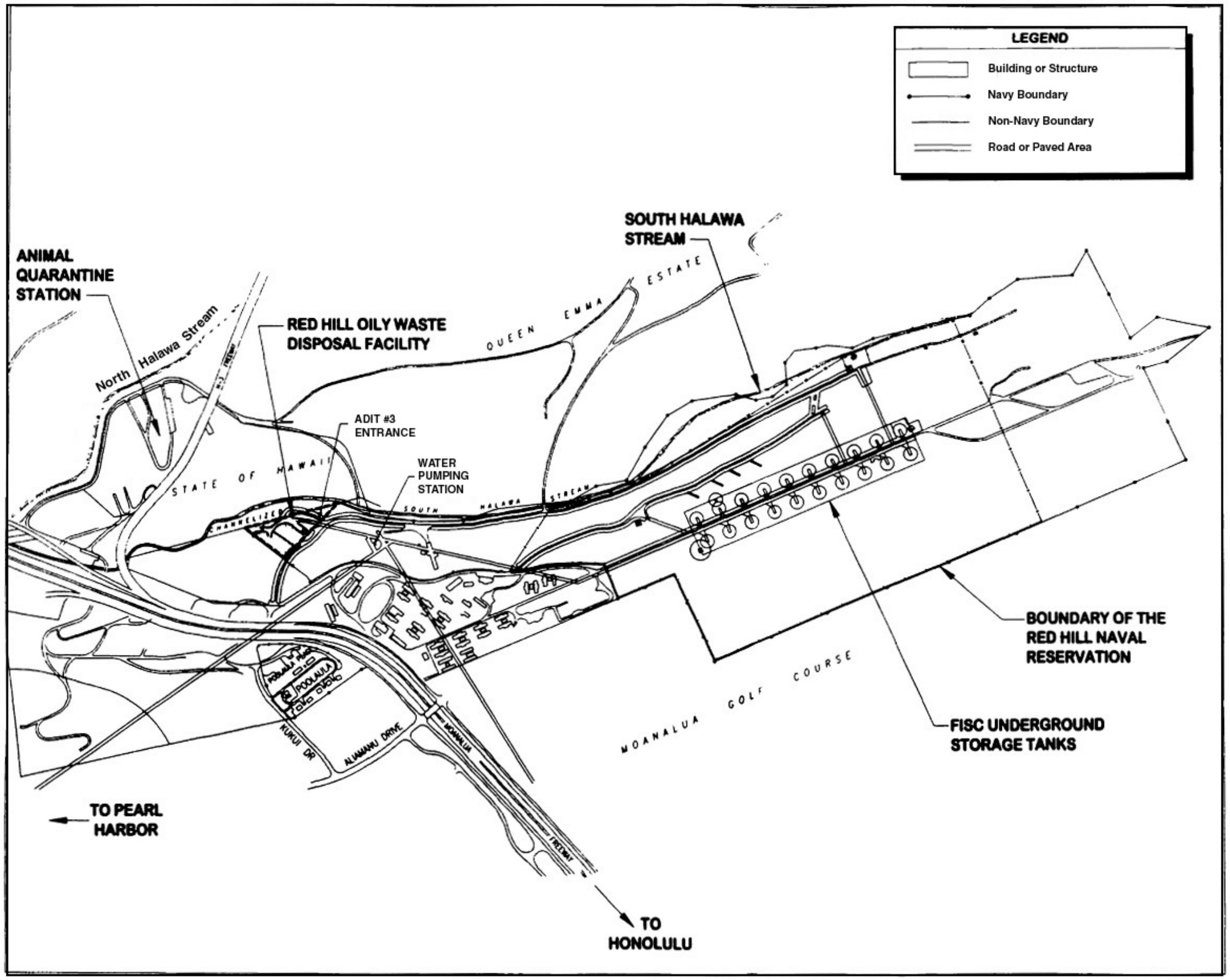


Figure 14. Red Hill Oily Waste Disposal Facility (OWDF), Site Details

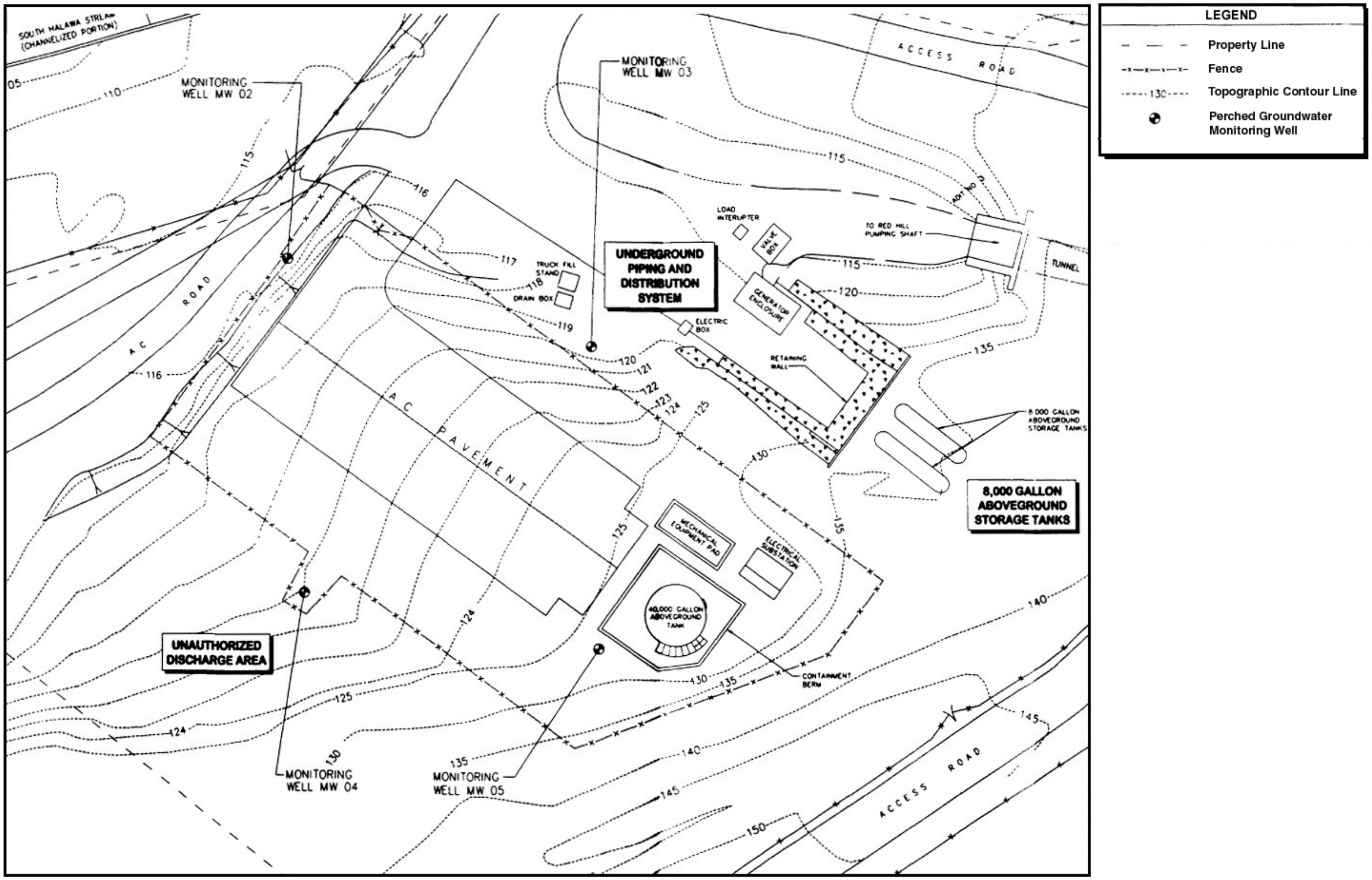


Figure 15. Location Map, Aiea Laundry, Pearl Harbor Naval Complex, Aiea, Hawaii

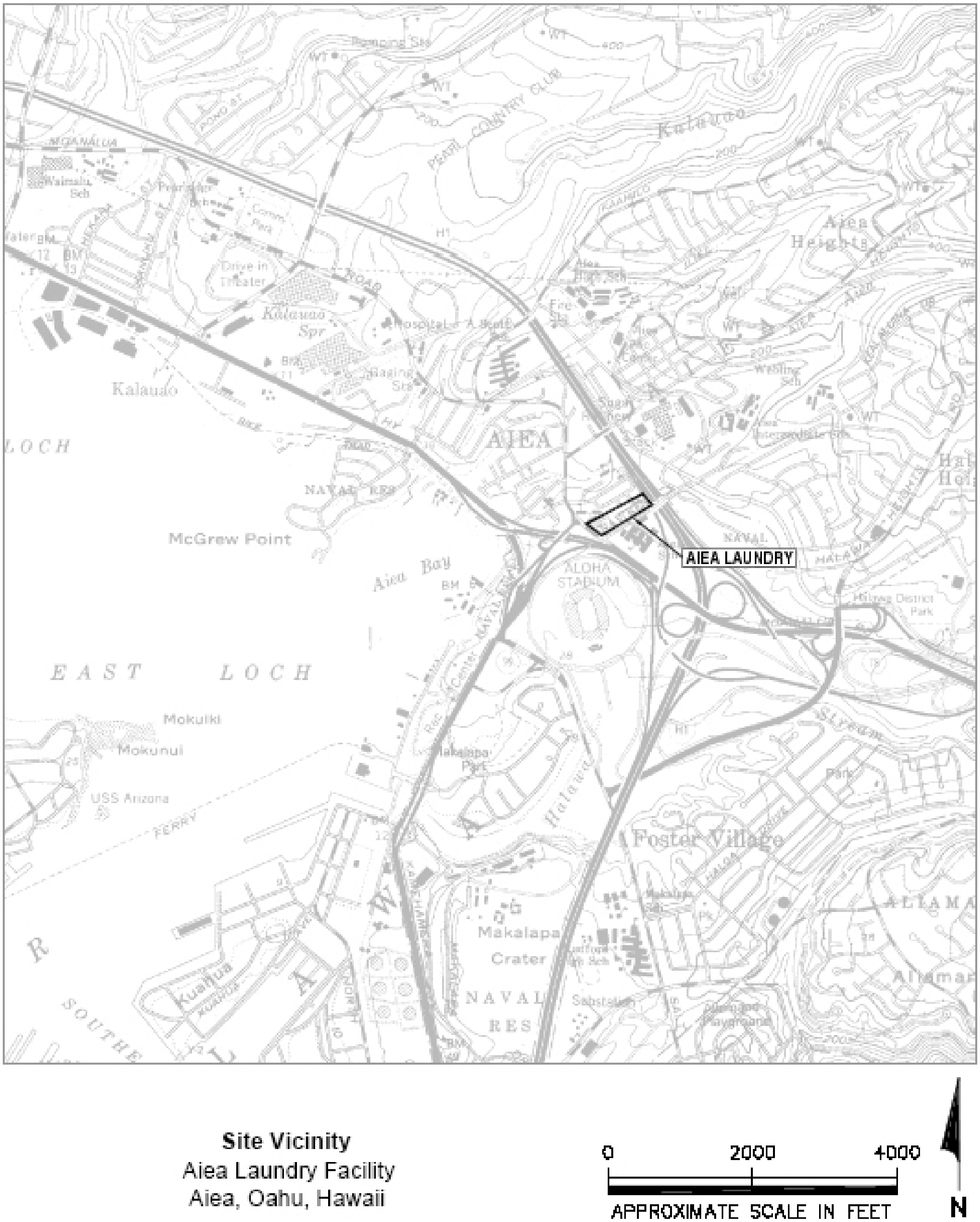


Figure 16. Aiea Laundry, Site Details

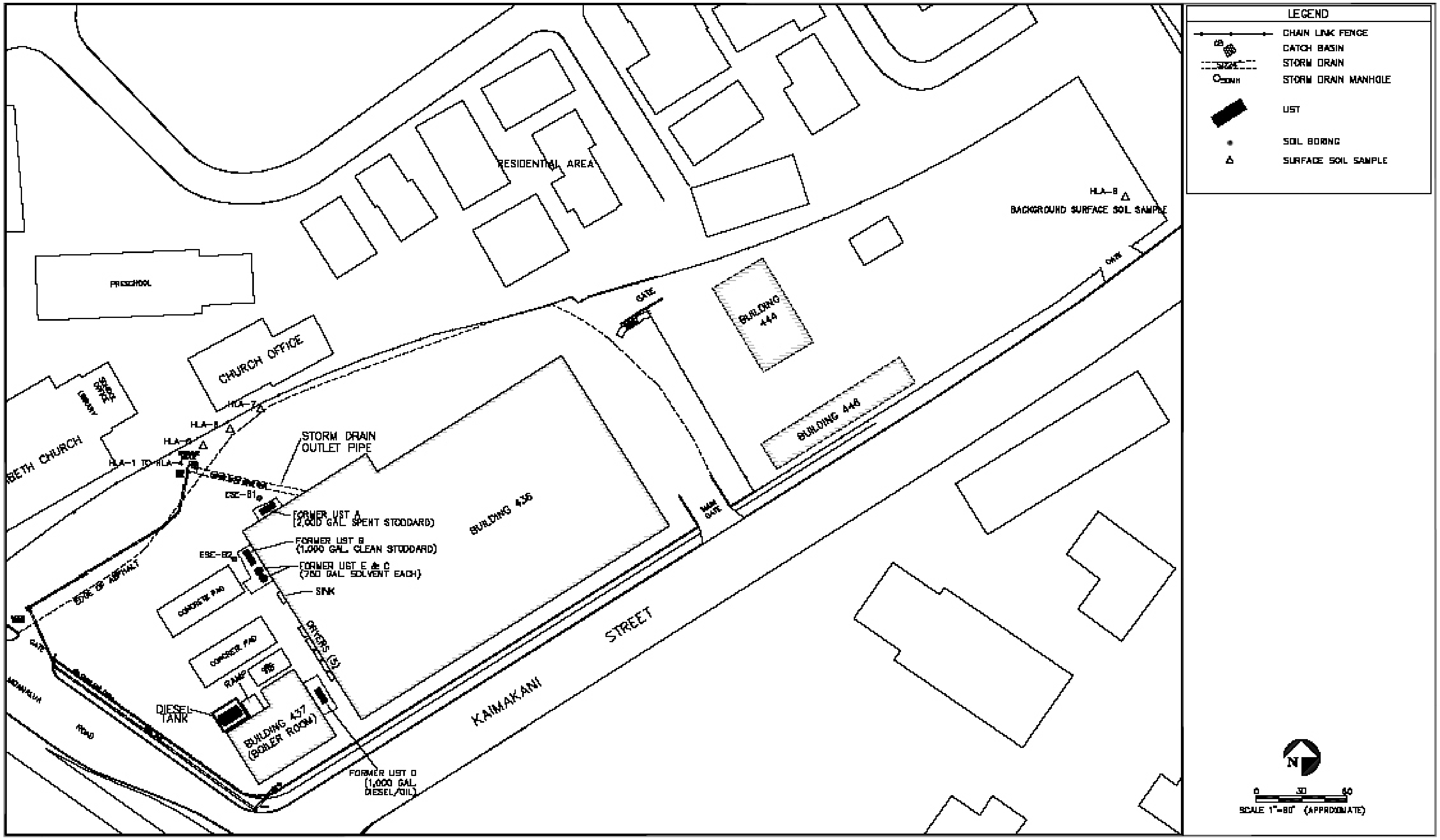
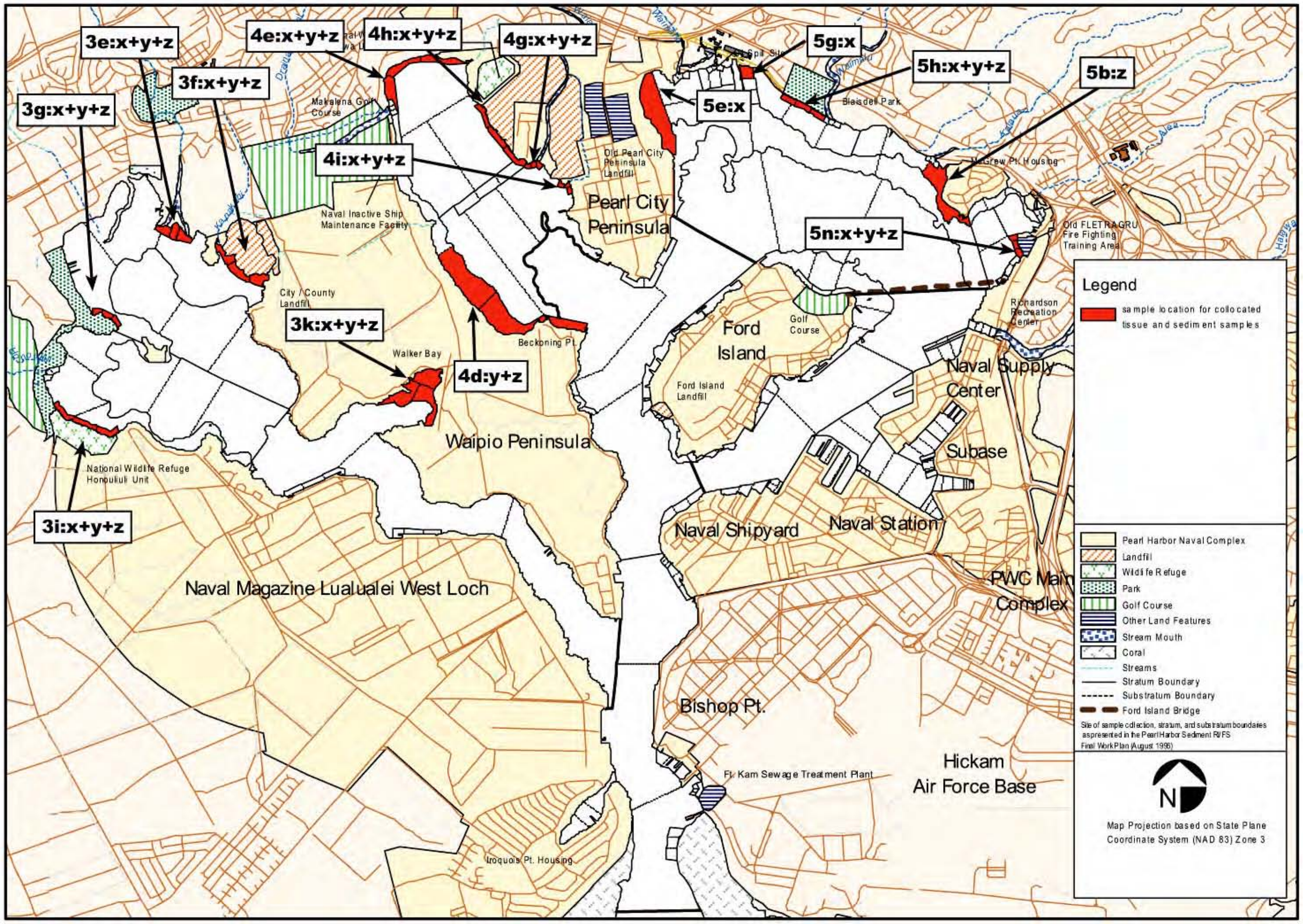


Figure 17. Locations of Fish and Sediment Samples Collected From Areas of Frequent Fishing and Crabbing



Appendices

Appendix A. ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Ambient
Surrounding (for example, ambient air).

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

mg/kg
milligram per kilogram.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
parts per billion.

ppm
parts per million.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public meeting
A public forum with community members for communication about a site.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Substance
A chemical.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Center for Environmental Health (CDC) (http://www.cdc.gov/nceh/dls/report/glossary.htm)
National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

Appendix B. Overview of ATSDR's Methodology for Evaluating Potential Public Health Effects

Methodology

Comparing Environmental Data to Comparison Values

A comparison value is used by ATSDR to screen chemicals that require additional evaluation.

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations. Values that are overestimated are considered to be conservative.

For this public health assessment (PHA), the Agency for Toxic Substances and Disease Registry (ATSDR) selected contaminants for further evaluation by comparing the maximum environmental contaminant concentrations against conservative health-based comparison values. Comparison values are developed by ATSDR from available scientific literature concerning exposure and health effects. Comparison values are derived for each environmental medium (water, soil, air, and biota) and reflect an estimated contaminant concentration that is not expected to cause harmful health effects, assuming a standard daily contact rate (for example, the amount of water or soil consumed or the amount of air breathed) and representative body weight. Because the concentrations reflected in comparison values are much lower than those that have been observed to cause adverse health effects, comparison values are protective of public health in essentially all exposure situations. As a result, concentrations detected at or below ATSDR's comparison values are not considered for further evaluation.

ATSDR's comparison values include the cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEGs). These are nonenforceable, health-based comparison values developed for screening environmental contamination for further evaluation. The U.S. Environmental Protection Agency's (EPA's) risk-based concentrations (RBCs) are health-based comparison values developed to screen sites not yet on the National Priorities List (NPL), respond rapidly to citizens' inquiries, and spot-check formal baseline risk assessments.

Essential nutrients (e.g., calcium, magnesium, phosphorous, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, screening guidelines do not exist for them. They are found in many foods, such as milk, bananas, and table salt.

While concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. Comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure. An environmental concentration alone will not cause an adverse health outcome. If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant and other epidemiology studies.

Comparing Estimated Doses to Health Guideline Values

> An exposure dose, expressed in milligrams per kilogram per day (mg/kg/day), represents the amount of contaminant mass that an individual is assumed to inhale, ingest, or touch (in milligrams), divided by the body weight of the individual (in kilograms) each day.

If chemical concentrations are above comparison values, ATSDR further evaluates the chemical and potential exposure. ATSDR does this by calculating exposure doses and comparing the doses to protective health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's reference doses (RfDs). Estimated exposure doses that are less than health guideline values are not considered to be of health concern. ATSDR's MRLs and EPA's RfDs are estimates of the daily human exposure to hazardous substances that are likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.

When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure (see Table B-1). Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several conservative assumptions to estimate exposures.

The following general equation was used to calculate exposure doses:

$$\text{Estimated exposure dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

- C: Concentration
- IR: Intake rate
- EF: Exposure frequency, or number of exposure events per year of exposure
- ED: Exposure duration, or the duration over which exposure occurs
- BW: Body weight
- AT: Averaging time, or the period over which cumulative exposures are averaged

MRLs and RfDs are generally based on the most sensitive end point considered to be of relevance to humans. While estimated doses that are less than these values are not considered to be of health concern, exposure to levels above the MRL or RfD does not automatically mean that adverse health effects will occur. To maximize human health protection, the values have built-in uncertainty or safety factors, making them considerably lower than levels at which health effects have been observed. The result is that even if a dose is higher than the health guideline, it does not necessarily follow that harmful health effects will occur. Rather, it is an indication that ATSDR should further examine the harmful effect levels reported in the scientific literature and more fully review exposure potential.

Estimating Cancer Risk

To screen for cancer effects, estimated chronic-exposure doses were multiplied by EPA's cancer slope factors (CSFs) to measure the relative potency of carcinogens. This calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts the probability of one additional cancer over background in a population of 1 million. Because conservative models are used to derive CSFs, the doses associated with these estimated hypothetical risks may be orders of magnitude lower than doses reported in the toxicology literature to cause carcinogenic effects. As such, a low cancer risk estimate indicates that the toxicology literature would support a finding that no excess cancer risk is likely. A higher cancer risk estimate, however, indicates that ATSDR should carefully review the toxicology literature before making conclusions about potential cancer risks.

Comparing Estimated Doses to Health Effects Levels

If the MRLs or RfDs are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies and experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

When comparing actual health effect levels in the scientific literature, ATSDR tries to estimate more realistic exposure scenarios to use for comparison. In this level of the evaluation, an average concentration of the environmental media, representative of the expected exposure, may be used to calculate exposure doses.

Sources for Health-Based Guidelines

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects at PHNC. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or by contacting the National Technical Information Service (NTIS) at 1-800-553-6847. EPA also develops health effects guidelines, and in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, please call EPA's IRIS hotline at 1-301-345-2870 or e-mail Hotline.IRIS@epamail.epa.gov.

Chemicals Without Health-Based Guidelines

There are a few chemicals that do not have health guidelines. In some cases, ATSDR tried to identify a similar chemical and use the substitute chemicals' health guidelines in the evaluation (e.g., acenaphthene's health guideline was used to evaluate the level of acenaphthylene detected). In other cases, ATSDR looked more closely at the chemical's prevalence, the detected concentrations, and at other scientific literature to determine whether that chemical was likely to pose a health concern.

Pearl Harbor Fish and Crabs

It is standard protocol to analyze the whole bodies of organisms when evaluating ecological concerns and fillets/edible portions when evaluating human health concerns. The Navy sampled whole fish, whole crabs, and fish fillets during the Pearl Harbor sediment study, since the data were collected for both ecological and human health risk assessments. The whole fish and whole crab samples were analyzed for metals, butyltins, polycyclic aromatic hydrocarbons (PAHs), semivolatile organic compounds (SVOCs), chlorinated pesticides, organophosphorous pesticides, triazine pesticides, herbicides, dioxins/furans, polychlorinated biphenyls (PCBs), and ordnance-related compounds. The fish fillet samples were only analyzed for metals, chlorinated pesticides, dioxins/furans, and PCBs. However, many of the additional chemicals sampled in the whole fish and whole crab samples were not detected. Because the fish fillet samples were not analyzed for all chemicals, ATSDR evaluated the data for all three sample types, then noted where using whole samples may influence the evaluation.

ATSDR used average chemical concentrations to calculate exposure doses to estimate a more probable exposure. This approach is taken because it is highly unlikely that anyone would ingest fish or crab with the maximum concentration on a daily basis and for an extended period of time because not every fish or crab contains the maximum detected concentration of any given chemical. Therefore, it is more likely that fish or crab containing a range of concentrations would be ingested over time. In addition, several chemicals were not detected in all samples collected. Therefore, fish or crab without any chemical contamination could also be consumed.

ATSDR calculated exposure doses for *all* the chemicals detected in the fish fillet, whole fish, and crab samples.[1] ATSDR assumed that an adult eats 85 grams (3 ounces (oz.)) of fish per day—which equals about 2.5 fish meals each week (one meal = 8 oz.)—and 24 grams (0.85 oz.) of crab per day—which equals about three crab meals a month. ATSDR assumed that a child eats 34 grams (1.2 oz.) of fish per day—which equals about two fish meals each week (one meal = 4 oz.)—and 9 grams (0.32 oz.) of crab per day—which equals a little over two crab meals each month.

> In 1998, the Hawaii Department of Health issued a fish advisory for Pearl Harbor, as a precautionary measure in response to fish and crab samples collected by the Navy.

Under these assumptions, the exposure doses for most of the chemicals were below health guidelines, and therefore not of health concern. However, five metals, one chlorinated pesticide, one herbicide, one ordnance-related compound, dioxins/furans, and PCBs exceeded health guideline values (see Table B-2). Therefore, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential for these chemicals.

[1] Semivolatile organic compounds were not detected in the fish or crab samples.

Metals

Antimony

Antimony is a silvery white metal that is naturally found in the environment. It can enter the body when food contaminated with it is eaten. After a few hours, a small amount enters the bloodstream and mostly distributes to the liver, lungs, intestines, and spleen. Antimony then leaves the body in urine and feces over several weeks. Consuming large quantities (19 mg/kg) may induce vomiting, which prevents most of the antimony from entering the bloodstream (ATSDR 1992).

Antimony was not detected in the crab samples. The whole fish exposure doses for both adults and children were below the noncancer health guideline, and therefore not of health concern. Only the fish fillet exposure dose for children was slightly above the health guideline (see Table B-2).

The oral health guideline for antimony is based on a study in which health effects were seen in rats exposed to 3.5×10^{-1} milligrams per kilogram per day (mg/kg/day) of antimony in their drinking water (Schroeder et al. 1970). The estimated exposure dose for children eating fish fillets is a thousand times lower than this health effects level (4.7×10^{-4} mg/kg/day; see Table B-2). Therefore, ATSDR does not expect that eating fish and crabs from Pearl Harbor containing the detected levels of antimony would cause harmful health effects.

Arsenic

Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen). The organic forms of arsenic are usually less toxic than the inorganic forms (ATSDR 2000a). Arsenic can be found in most foods, with seafood, particularly shellfish, containing the highest concentrations (FDA 1993). Therefore, ingesting fish and shellfish containing arsenic is one way arsenic can enter the body. However, most of the arsenic in fish and shellfish is in the less harmful organic form (ATSDR 2000a; FDA 1993).

Once arsenic is in the body, the liver changes some of the inorganic arsenic into the less harmful organic form (i.e., by methylation). This process is effective as long as the dose of inorganic arsenic remains below 5.0×10^{-2} mg/kg/day (ATSDR 2000a). Both inorganic and organic forms of arsenic leave the body in urine. Studies have shown that 45 to 85 percent of the arsenic is eliminated within 1 to 3 days (Buchet et al. 1981; Crecelius 1977; Mappes 1977; Tam et al. 1979); however, some will remain for several months or longer.

Because inorganic arsenic is much more harmful than organic arsenic, ATSDR based its health assessment on the levels of inorganic arsenic that are present. In fish and shellfish, generally about 1 to 20 percent of the total arsenic is in the more harmful inorganic form (ATSDR 2000a; Francesconi and Edmonds 1997; NAS 2001; FDA 1993). The U.S. Food and Drug Administration (FDA) proposes that 10 percent of the total arsenic be estimated as inorganic arsenic (FDA 1993). To be protective, ATSDR used a conversion factor of 20 percent to calculate the estimated dose to reflect inorganic arsenic levels in fish and crab from Pearl Harbor (i.e., ATSDR conservatively assumed that 20 percent of the total arsenic detected was inorganic arsenic) (see Table B-2).

Noncancer Health Effects

Daily exposure to the average concentrations of inorganic arsenic in fish and crab from Pearl Harbor would result in exposure doses ranging from 6.0×10^{-5} to 2.3×10^{-4} mg/kg/day for adults and 1.1×10^{-4} to 3.8×10^{-4} mg/kg/day for children (see Table B-2). As noted above, the metabolism of inorganic arsenic (i.e., how it is broken down in the body) has been extensively studied in humans and animals. ATSDR's estimated doses are well below those that inhibit the body's ability to detoxify or change arsenic to nonharmful forms (doses greater than 5.0×10^{-2} mg/kg/day inhibit detoxification). Therefore, the amount of arsenic that a person consumes in fish and crab from Pearl Harbor should be controlled by normal metabolic processes in the body.

Scientific reports suggest that some dermal health effects could result from ingesting a lower dose of arsenic. Hyperkeratosis (thickening of the skin) and hyperpigmentation (darkening of the skin) were reported in humans exposed to 1.4×10^{-2} mg/kg/day of arsenic in their drinking water for more than 45 years (Tseng et al. 1968). However, there is much uncertainty surrounding the reported dose. Because estimates of water intake and dietary arsenic are highly uncertain in this and similar studies, some scientists argue that reported effects may actually be associated with doses higher than 1.4×10^{-2} mg/kg/day. Regardless, ATSDR's estimated exposure doses are well below this dermal health effect level.

The FDA regulates the level of arsenic in food. To limit the intake of arsenic to a level considered to be safe, FDA set an action level of 76 mg/kg for crustaceans and 86 mg/kg for molluscan bivalves (FDA 1993). The fish and crab samples collected from Pearl Harbor contain arsenic concentrations well below these levels (maximum concentration = 6.6 mg/kg).

The metabolism of arsenic has been well studied in people, and the estimated exposure doses for eating fish and crab from Pearl Harbor are within the body's capability to metabolize arsenic. Therefore, ATSDR does not expect that people who eat the fish and crabs would experience related adverse noncancer health effects from arsenic.

Cancer Health Effects

The U.S. Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and EPA have all independently determined that inorganic arsenic is carcinogenic to humans (ATSDR 2000a). Skin cancer was reported for people exposed to 1.4×10^{-2} mg/kg/day of arsenic in their water for more than 45 years (Tseng et al. 1968). As explained above, scientists argue that this cancer effect level (CEL) may be underestimated (i.e., doses associated with cancer may actually be higher). Additional CELs in the literature generally ranged from 0.01 to 0.05 mg/kg/day (ATSDR 2000a). The estimated lifetime doses are about two orders of magnitude below these levels (6.0×10^{-5} to 2.3×10^{-4} mg/kg/day; see inorganic arsenic adult doses in Table B-2).[2] Additionally, ATSDR conservatively assumed that 20 percent

[2] The adult exposure scenario evaluates being exposed to contaminants in fish and crabs over a lifetime (i.e., 70 years).

of the total arsenic is in the inorganic form. Even with these protective assumptions, the estimated doses are below levels of health concern for cancer effects. As such, no excess cancers from arsenic exposures are expected from consumption of fish and crabs caught in Pearl Harbor.

Chromium

Chromium can be found in three main forms—chromium 0, chromium III (also known as trivalent chromium), and chromium VI (also known as hexavalent chromium). Chromium VI is more harmful than chromium III, an essential nutrient required by the body. Although some or all of the chromium detected in fish and crabs from Pearl Harbor could be chromium III; as a conservative approach to the health evaluation, ATSDR assumed that all of the chromium was the more harmful chromium VI.

Chromium VI is more easily absorbed than chromium III; therefore, eating fish and crab containing chromium can lead to harmful forms of chromium entering the body. However, once inside the body, the more harmful chromium VI is converted into the essential nutrient, chromium III. In addition, most of the chromium ingested will exit the body in feces within a few days and never enter the bloodstream. Only a very small amount (0.4 to 2.1 percent) of chromium can pass through the walls of the intestine and enter the bloodstream (Anderson et al. 1983; Anderson 1986; Donaldson and Barreras 1966).

Noncancer Health Effects

The fish fillet and crab exposure doses for both adults and children were below the noncancer health guideline; and therefore, not of health concern. The whole fish exposure doses were at (adults) or above (children) the health guideline; therefore, the following discussion focuses on chromium found in the whole fish samples (see Table B-2).

The oral health guideline for chromium VI is based on a study in which no adverse health effects were reported in animals exposed to 2.5 mg/kg/day of chromium VI in their drinking water (MacKenzie et al. 1958). In comparison, rats that ate 1,468 mg/kg/day of chromium III experienced no adverse health effects (Ivankovic and Preussman 1975). The estimated exposure doses for both adults and children are thousands of times lower than these no-adverse-health-effects levels (3.0×10^{-3} mg/kg/day and 5.2×10^{-3} mg/kg/day, respectively; see Table B-2). Therefore, ATSDR does not expect that eating fish and crabs from Pearl Harbor containing the detected levels of chromium would cause harmful noncancer health effects.

The FDA regulates the level of chromium in food. To limit the intake of chromium to a level considered to be safe, FDA set an action level of 12 mg/kg for crustaceans and 13 mg/kg for molluscan bivalves (FDA 1993). All of the fish and crabs collected from Pearl Harbor contained chromium concentrations below these levels (maximum concentration = 6.4 mg/kg).

Cancer Health Effects

DHHS has determined that certain chromium VI compounds are known human carcinogens when inhaled. IARC has determined that chromium VI is carcinogenic to humans and chromium 0 and chromium III are not classifiable as to their carcinogenicity. EPA has determined that chromium VI in air is a human carcinogen, but insufficient evidence exists to determine whether chromium VI and chromium III in food and water are human carcinogens (ATSDR 2000b). Therefore, despite its carcinogenicity classification, consuming fish and crabs with chromium is not expected to result in an increase in cancer because the available scientific evidence suggests that oral exposure to chromium would not result in cancer. Animal studies involving chromium ingestion have found no evidence of carcinogenicity (Ivankovic and Preussmann 1975). As such, no excess cancers from chromium exposures are expected from consumption of fish and crabs caught in Pearl Harbor.

Copper

Copper is a naturally occurring metal. Once ingested, it is absorbed by the stomach and small intestines, enters the bloodstream, and is distributed throughout the body. However, the body has homeostatic mechanisms that effectively block high levels from entering the bloodstream (ATSDR 2002b). Several factors affect the absorption of copper, including competition with other metals, such as cadmium, iron, and zinc; the amount of copper in a person's diet; and age (ATSDR 2002b).

Copper is essential for good health. It is required for normal functioning of at least 30 enzymes (ATSDR 2002b). It aids in the absorption and utilization of iron and in the production of hemoglobin, which transports oxygen in the body. However, even though the body is very good at regulating how much copper enters the bloodstream, excessive intakes can cause harmful health effects (ATSDR 2002b).

Copper was not detected in the fish fillet samples. The crab exposure doses for both adults and children were below the noncancer health guideline, and therefore, not of health concern. Only the whole fish exposure dose for children was slightly above the health guideline (see Table B-2).

Very few toxicological and epidemiological studies are available for copper. Those that are available suffer from design flaws and involve only a few subjects (NAS 2001). The National Academy of Sciences reports that no adverse effects were observed at doses of 10 mg/day (NAS 2001). Therefore, for comparison, ATSDR calculated a daily consumption from exposure to the average concentration of copper in fish using a modification of the dose equation (dose = concentration × IR); and compared this daily dose to the level determined by the National Academy of Sciences to be safe (10 mg/day).

Eating fish from Pearl Harbor would increase a child's daily consumption of copper by about 0.5 mg/day. The median copper intake in the United States from food is approximately 1.0 to 1.6 mg/day (NAS 2001). The relatively small daily increases in consumption (from eating fish from Pearl Harbor) are not likely to increase a child's daily dose above the National Academy of Sciences' no-observed-adverse-effect-level (NOAEL) of 10 mg/day. Therefore, copper concentrations in fish and crabs from Pearl Harbor are not expected to cause adverse health effects.

Iron

Iron is an important mineral, assisting in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues. Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency anemia is a condition that occurs when the body does not receive enough iron.

Iron was not detected in the fish fillet samples. The crab exposure doses for both adults and children were below the noncancer health guideline; and therefore, not of health concern. The whole fish exposure doses for adults and children were above the health guideline; therefore, the following discussion focuses on iron found in the whole fish samples (see Table B-2).

The oral health guideline for iron is based on dietary intake data collected as part of EPA's Second National Health and Nutrition Examination Survey, in which no adverse health effects were associated with average iron intakes of 0.15 to 0.27 mg/kg/day. These levels were determined to be sufficient for protection against iron deficiency, but also low enough not to cause harmful health effects.

Eating Pearl Harbor fish would result in exposure doses of 1.1 mg/kg/day for adults and 2.0 mg/kg/day for children. These estimated doses exceed the NOAELs of 0.15 to 0.27 mg/kg/day. However, estimated doses that exceed the NOAELs do not automatically indicate that an adverse health effect will occur because NOAELs indicate a level in which no adverse health effects were observed. Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998).

Generally, iron is not considered to cause harmful health effects except when swallowed in extremely large doses, as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). However, doses of this magnitude are generally the result of children ingesting iron pills. For comparison, ATSDR calculated a daily consumption from exposure to the average concentration of iron in sediment using a modification of the dose equation (dose = concentration × IR).

Exposure to the average concentration of iron in Pearl Harbor fish would substantially increase a child's daily consumption of iron by about 32 mg/day. The median daily intake of dietary iron is roughly 11 to 13 mg/day for children 1 to 8 years old and 13 to 20 mg/day for adolescents 9 to 18 years old (NAS 2001). Therefore, the daily increases in consumption (from incidentally ingesting Pearl Harbor fish) are not likely to cause a child's daily dose to exceed levels known to induce poisoning (e.g., more than 200 mg/event). Further, iron was not detected in fish fillets—the edible portion of the fish—so eating fish fillets would not result in harmful health effects (see Table B-2). The iron concentrations detected in the whole fish are likely the result of including bones in the samples. Therefore, ATSDR does not expect that eating fish and crabs from Pearl Harbor would cause harmful health effects.

Chlorinated Pesticides

Dieldrin

Dieldrin is a man-made chemical that was used as an insecticide until 1970, when the U.S. Department of Agriculture canceled all uses. Although EPA approved the use of dieldrin for killing termites in 1972, in 1987 the manufacturer voluntarily canceled the registration (ATSDR 2002a). Aldrin and dieldrin are structurally similar chemicals. Sunlight and bacteria in the environment can change aldrin to dieldrin. Therefore, you can find dieldrin in places where aldrin was originally released (ATSDR 2002a).

Studies in animals show that dieldrin enters the body quickly after exposure and is stored in their fat. It stays in fat tissue for a long time and can change to other products. It can take many weeks or years for dieldrin and its breakdown products to leave a person's body. Animals or fish that eat other animals have levels of dieldrin in their fat many times higher than animals or fish that eat plants (ATSDR 2002a).

Noncancer Health Effects

> FDA regulates the level of dieldrin in food. To limit the intake of dieldrin to a level considered to be safe, FDA set an action level of 0.3 mg/kg for the edible portion of fin fish and shellfish (FDA 2001). All of the fish and crabs collected from Pearl Harbor contained dieldrin concentrations well below this level (maximum concentration = 0.035 mg/kg).

The noncancer health guideline is 5.0×10^{-5} mg/kg/day for chronic exposure to dieldrin. The estimated exposure doses for adults and children eating fish and crab are below this protective level (see Table B-2). Remember that health guidelines are estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects. They have built-in uncertainty or safety factors, making them considerably lower than levels at which health effects have been observed. Estimated doses that are less than these values are not considered to be of health concern. Therefore, ATSDR does not expect that eating fish or crabs from Pearl Harbor with the detected levels of dieldrin would cause harmful noncancer health effects.

Cancer Health Effects

DHHS and IARC have determined that dieldrin is not classifiable as to its carcinogenicity to humans (ATSDR 2002a). EPA has determined that dieldrin is a probable human carcinogen because orally administered dieldrin produced significant increases in tumor responses in seven different strains of mice (EPA 2005). However, lifetime exposure to the average concentration of dieldrin in fish and crabs from Pearl Harbor is not expected to result in an increase in cancer because the expected lifetime doses (4.8×10^{-7} to 1.6×10^{-5} mg/kg/day; see adult doses in Table B-2) are more than 10,000 times lower than the CELs reported in the scientific literature (CELs ranged from 0.33 to 1.3 mg/kg/day; ATSDR 2002a). Therefore, no excess cancers from dieldrin exposures are expected from consumption of fish and crabs caught in Pearl Harbor.

Herbicides

2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)

MCPP is an odorless, white to light brown crystalline solid that is used as a selective post-emergence herbicide for control of broad leaf weeds (HSDB 2004).

MCPP was not sampled in fish fillets and was not detected in the whole crab samples. It was detected in 2 of the 15 whole fish samples. The whole fish exposure doses for adults and children were slightly above the health guideline (see Table B-2) in those two samples.

The noncancer oral health guideline for MCPP is based on a study in which no adverse health effects were seen in rats fed 3 mg/kg/day of MCPP in their diet (BASF Aktiegesellschaft 1985). Additional animal studies showed no adverse health effects ranging from 2.5 to 125 mg/kg/day, but then also showed health effects at doses as low as 3.4 mg/kg/day (EPA 2005). The estimated exposure doses for adults and children eating whole fish are about two orders of magnitude below the lowest health effects levels (3.8×10^{-2} mg/kg/day and 6.6×10^{-2} mg/kg/day, respectively; see Table B-2).

ATSDR does not expect that eating fish and crabs from Pearl Harbor containing the detected levels of MCPP would cause harmful health effects. However, relevant data from the scientific literature are limited. Further, IARC has determined that the chlorophenoxy herbicides are possibly carcinogenic to humans (IARC 1987), but CELs are not currently available to allow a comparison.

Ordnance-Related Compounds

2,4,6-Trinitrotoluene (TNT)

TNT is a manufactured explosive compound. It can enter the bloodstream and distribute throughout the body when a person consumes food contaminated with TNT. Animal studies indicate that about 60 percent of TNT is absorbed when ingested (ATSDR 1995). The liver then changes it into several different compounds, which leave the body in urine. Animal studies show that almost all of the TNT breaks down and leaves the body within 24 hours (ATSDR 1995).

Noncancer Health Effects

TNT was not sampled in fish fillets. The whole crab exposure doses for both adults and children were below the noncancer health guideline; and therefore, not of health concern. Only the whole fish exposure dose for children was slightly above the health guideline (see Table B-2).

The oral health guideline for TNT is based on a study in which no adverse health effects were seen in dogs fed 0.5 mg/kg/day of TNT (DOD 1983). Supporting animal studies showed that dogs were the most sensitive species tested. The estimated exposure dose for children eating whole fish is a thousand times lower than this health effects level (5.3×10^{-4} mg/kg/day; see Table B-2). Therefore, ATSDR does not expect that eating fish or crabs from Pearl Harbor with the detected levels of TNT would cause harmful noncancer health effects.

Cancer Health Effects

IARC has determined that TNT is not classifiable as to its carcinogenicity to humans (IARC 1996). EPA has classified TNT as a possible human carcinogen (EPA 2005). However, lifetime exposure to the average concentration of TNT in fish and crabs from Pearl Harbor is not expected to result in an increase in cancer because the expected lifetime doses (3.0×10^{-4} mg/kg/day and 1.2×10^{-5} mg/kg/day; see adult doses in Table B-2) are more than 10,000 times lower than the CELs reported in the scientific literature (1.5 mg/kg/day and 50 mg/kg/day; ATSDR 1995). As such, no excess cancers from TNT exposures are expected from consumption of fish and crabs caught in Pearl Harbor.

Dioxins/Furans

Dioxins are a family of 75 different compounds that have varying harmful effects. They are divided into eight groups based on the number of chlorine atoms, which can be attached to the dioxin/furan molecule at any one of eight positions. The name of each dioxin or furan indicates both the number and the positions of the chlorine atoms. For example, the dioxin with four chlorine atoms at positions 2, 3, 7, and 8 on the molecule is called 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), which is one of the most toxic of the dioxins to mammals and has received the most attention (ATSDR 1998).

The most common way for dioxins to enter the body is as contaminants in food. In general, absorption of dioxins depends on how they are ingested and the specific type of dioxin that is ingested—about 87 percent of TCDD was absorbed in one human volunteer who ingested a single dose (Poiger and Schlatter 1986). Dioxins are lipophilic, meaning that they are attracted to lipids (fats) and tend to accumulate in body parts that have more fat, such as the liver. They can also concentrate in maternal milk. The body can store dioxins in the liver and body fat for many years before eliminating them.

A toxic equivalency factor (TEF) approach to evaluating health hazards has been developed for dioxins (for details, see ATSDR 1998). In short, the TEF approach compares the relative potency of individual dioxins and furans with that of TCDD, the best-studied member of this chemical class. The concentration or dose of each dioxin and furan is multiplied by its TEF to produce a toxic equivalent (TEQ), and the TEQs are added to give the total toxic equivalency. The total toxic equivalency is then compared to reference exposure levels for TCDD expected to be without significant risk for producing health hazards.

Noncancer Health Effects

Consuming fish and crabs from Pearl Harbor would result in exposure doses ranging from 7.2×10^{-10} to 1.7×10^{-9} mg/kg/day for adults and 1.3×10^{-9} to 2.8×10^{-9} mg/kg/day for children (see Table B-2). The oral health guideline for the most toxic dioxin, TCDD, is based on a study in which health effects were observed in female rhesus monkeys fed a diet containing 1.2×10^{-7} mg/kg/day of TCDD (Schantz et al. 1992). The estimated exposure doses are two orders of magnitude lower than this health effects level. Further, dioxins are a well-studied family of compounds; this dose is the lowest health effects level reported in the 33 chronic-duration studies on TCDD. Therefore, ATSDR does not expect that eating fish or crabs from Pearl Harbor with the detected levels of dioxin would cause harmful noncancer health effects.

Cancer Health Effects

DHHS has determined that it is reasonable to expect that TCDD may cause cancer. IARC has determined that TCDD can cause cancer in people, but that it is not possible to classify other dioxins as to their carcinogenicity to humans. EPA has determined that TCDD is a probable human carcinogen (ATSDR 1998). However, the estimated exposure doses from ingesting Pearl Harbor fish and crabs (7.2×10^{-10} to 1.7×10^{-9} mg/kg/day; see adult doses in Table B-2) are more than a million times below the CELs reported in the literature (CELs ranged from 0.0071–0.36 mg/kg/day; ATSDR 1998). Therefore, no excess cancers from dioxin exposures are expected from consumption of fish and crabs caught in Pearl Harbor.

Polychlorinated Biphenyls

PCBs are a group of synthetic organic chemicals that can cause a number of harmful effects. There are no known natural sources of PCBs in the environment. Because they do not burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in August 1977, because there was evidence that PCBs build up in the environment and may cause harmful effects (ATSDR 2000c).

PCBs enter the environment as mixtures containing a variety of individual chlorinated biphenyl components, known as congeners. There are 209 possible PCB congeners. Aroclors are commercial PCB mixtures that contain different congener compositions. Aroclors widely used in the United States were 1016, 1232, 1242, 1248, 1254, and 1260. (The first two digits indicate the type of mixture and second two digits reveal how much chlorine by weight is in the mixture.)

The mixture of PCB congeners found in fish will not exactly match the original Aroclor composition because each congener has different physical and chemical properties that affect how it behaves in the environment. For example, less chlorinated PCBs (1–4 chlorines) are readily taken up by organisms, but are also readily eliminated and metabolized. The most highly chlorinated congeners (7–10 chlorines) occur in low concentrations in the environment. They tend to bind tightly with soil, sediment, and organic matter. Thus, these PCBs are also not significantly bioaccumulated (ATSDR 2000c). On the other hand, the penta-, hexa-, and some hepta-PCBs (5, 6, and 7 chlorines) are both bioavailable and resistant to degradation in organisms. These PCBs tend to bioaccumulate in organisms to the greatest extent (ATSDR 2000c).

Noncancer Health Effects

The oral health guideline for PCBs is based on a study in which health effects (decreased antibody response) were observed in female rhesus monkeys chronically exposed to 5.0×10^{-3} mg/kg/day of Aroclor 1254 (Arnold et al. 1993; Tryphonas et al. 1989, 1991). This is the lowest-observed-adverse-effect-level (LOAEL) identified in the scientific literature for chronic exposure to PCB mixtures. However, this was also the lowest dose tested; therefore, a NOAEL was not established for this study. Using the assumed fish and shellfish ingestion rates described previously, consuming fish from Pearl Harbor would result in estimated exposure doses ranging from 1.1×10^{-5} to 3.8×10^{-4} mg/kg/day for adults and 1.8×10^{-5} to 6.7×10^{-4} mg/kg/day for children (see Table B-2). These estimated doses are below the lowest health effect level reported in the scientific literature, but only an order of magnitude lower. Typically, estimated exposure doses that are within an order of magnitude of a LOAEL warrant some concern. Therefore, it would be prudent public health practice to limit consumption of fish and crabs from Pearl Harbor.

There are several methods available to estimate health “risks” associated with fish consumption. EPA developed risk-based consumption limits for the general adult population (EPA 2000). The concentration in the fish tissue is compared to the consumption limit to determine the maximum number of fish meals per month that can be safely eaten. According to EPA’s guidance, fish from Pearl Harbor should not be eaten due to the levels of PCBs detected in the fish fillets.

Cancer Health Effects

DHHS has stated that PCBs may reasonably be anticipated to be carcinogens. Both EPA and IARC have determined that PCBs are probably carcinogenic to humans. Cancer incidence was studied in cohorts of Swedish fishermen, who had high intakes of PCBs in fish (Svensson et al. 1995). There was an indication that the incidence of stomach cancer was elevated, but the results were confounded by exposure to other contaminants in the fish. The estimated exposure doses from ingesting Pearl Harbor fish and crabs (1.1×10^{-5} to 3.8×10^{-4} mg/kg/day; see adult doses in Table B-2) are well below the CELs reported in the literature (CELs ranged from 1.0 to 5.4 mg/kg/day in animals; no CELs exist for humans; ATSDR 2000c). As such, no excess cancers from PCB exposures are expected from consumption of fish and crabs caught in Pearl Harbor. However, the estimated doses approach levels for noncancer health effects. Because of the potential for noncancer effects, it would be prudent public health practice to follow the Hawaii Department of Health’s fish advisory and limit consumption of fish and crabs from Pearl Harbor.

Dioxin-Like PCBs

A portion of the PCB congeners fall into a category of “dioxin-like” PCBs. Because of their structure and mechanism of action, they exhibit toxic behavior similar to that of dioxins. However, their toxicity is 0.00001 to 0.1 times lower than that of TCDD, the most toxic dioxin. A TEF approach to evaluating health hazards has been developed and used to some extent to guide public health decisions (for details, see EPA 1996 and ATSDR 2000c). The TEF approach compares the relative potency of individual congeners with that of TCDD, the best-studied member of this chemical class. The concentration or dose of each dioxin-like congener is multiplied by its TEF to arrive at a TEQ, and the TEQs are added to give the total toxic equivalency. The total toxic equivalency is then compared to reference exposure levels for TCDD expected to be without significant risk for producing health hazards. This evaluation also provided results that suggest it would be prudent public health practice to limit consumption of fish and crabs from Pearl Harbor.

Pearl Harbor Sediments

Incidental Ingestion of Pearl Harbor Sediments

The maximum concentrations for most chemicals detected in Pearl Harbor sediments were below their respective health-based comparison values. Concentrations below these levels are considered safe in essentially all exposure situations. Chemicals with maximum concentrations that exceeded comparison values are listed in Table B-3. Remember, that it does not automatically mean that an environmental concentration that exceeds a comparison value is expected to produce harmful health effects. Comparison values are not thresholds of toxicity. They simply indicate to ATSDR that further evaluation is warranted. Therefore, ATSDR continued to evaluate exposures to Pearl Harbor sediments for those chemicals listed in Table B-3.

As the next step in the screening process, ATSDR calculated exposure doses using the average concentrations detected in Pearl Harbor sediments and the formula described in the "Methodology" section. ATSDR used the average concentration to calculate a more probable exposure dose. It is highly unlikely that anyone would incidentally ingest sediment containing the maximum concentration on a daily basis and for an extended period of time because not all the sediment contains the maximum concentration of any given chemical. Therefore, it is more likely that sediment containing a range of concentrations would be ingested over time.

People, particularly children, who fish in, play at, or walk along Pearl Harbor may be exposed to chemicals in the sediment through inadvertent hand-to-mouth activities. Young children play on the ground, engage in frequent hand-to-mouth activity, and often mouth objects. That means they have the greatest risk of exposure through more frequent and longer contact with sediment. ATSDR assumed that people could come in contact with Pearl Harbor sediments every day for 70 years. That contact could result in adults incidentally ingesting about 50 mg/kg of sediment, each day. This is equivalent to eating roughly 2 teaspoons of sediments a year. Due to their greater exposure potential, children were assumed to incidentally ingest 100 mg/kg of sediment each day.

Using these protective assumptions, only the child and adult exposure doses for iron exceeded health guideline values (see following evaluation). The resulting exposure doses for *all* other chemicals were below health guidelines and therefore not of health concern (see Table B-4). Further, ordnance, many of the pesticides, and most of the SVOCs were either not detected or detected infrequently (i.e., in less than 10 percent of the samples) in Pearl Harbor sediments. People can only be exposed to a chemical if they come in contact with that chemical. If no one comes in contact with a chemical (because it is not present), then no exposure occurs, so no health effects could occur.

Iron

Iron is an important mineral, assisting in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues. Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency anemia is a condition occurring when the body does not receive enough iron.

The oral health guideline for iron is based on dietary intake data collected as part of EPA's Second National Health and Nutrition Examination Survey, in which no adverse health effects were associated with average iron intakes of 0.15 to 0.27 mg/kg/day. These levels were determined to be sufficient for protection against iron deficiency, but also low enough not to cause harmful health effects.

Daily exposure to the average concentration (60,672 mg/kg) of iron in Pearl Harbor sediments would result in exposure doses of 0.043 mg/kg/day for adults and 0.38 mg/kg/day for children. The estimated dose for a child slightly exceeds the NOAELs of 0.15 to 0.27 mg/kg/day. However, estimated doses that slightly exceed the NOAELs do not indicate that an adverse health effect will occur because NOAELs indicate a level in which *no* adverse health effects were observed. Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998).

Generally, iron is not considered to cause harmful health effects except when swallowed in extremely large doses, such as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). Doses of this magnitude are generally the result of children ingesting iron pills. For comparison, ATSDR calculated a daily consumption from exposure to the average concentration of iron in sediment using a modification of the dose equation (dose = concentration × IR).

Exposure to the average concentration of iron in Pearl Harbor sediments would increase a child's daily consumption of iron by about 6 mg/day. The median daily intake of dietary iron is roughly 11 to 13 mg/day for children 1 to 8 years old and 13 to 20 mg/day for adolescents 9 to 18 years old (NAS 2001). Therefore, the daily increases in consumption (from incidentally ingesting Pearl Harbor sediments) are not likely to cause a child's daily dose to exceed levels known to induce poisoning (e.g., more than 200 mg/event). Therefore, ATSDR does not expect that people who contact Pearl Harbor sediments would experience harmful health effects.

Dermal Exposure to Pearl Harbor Sediments

Dermal exposure to chemicals detected below comparison values should not cause harmful health effects. In essentially all exposure situations, including dermal contact, comparison values are protective of public health. Therefore, only those chemicals detected above comparison values are evaluated for exposure through dermal contact (see Table B-3). Unlike the evaluation for incidental ingestion, dermal contact is not evaluated quantitatively through deriving exposure doses. Rather, this evaluation is a qualitative discussion of the chemical's potential to be absorbed into the body through the skin.

ATSDR generally considers dermal exposure to be a minor contributor to the overall exposure dose relative to contributors from ingestion. Many organic chemicals bind to organic matter in sediment, and are therefore not readily available for absorption by the skin. In addition, only the fraction of the contaminant that is in direct contact with the skin is amenable to absorption (ATSDR 2005).

- In general, unless the skin is damaged, metals are not readily absorbed through the skin.

- Butyltins and pesticides can be absorbed through the skin, but in much smaller amounts than what is absorbed through the stomach. Exposure to these chemicals through dermal contact results in doses much lower than for those in the incidental ingestion pathway.

- PAHs, PCBs, and dioxin/furans can also be absorbed through the skin and could lead to an increase in overall dose. Even with a conservative assumption that the doses expected to result from dermal exposure are equal to the doses from incidental ingestion, the cumulative exposure doses are still well below levels of health concern.

Therefore, dermal exposure to the chemicals detected in Pearl Harbor sediment is also not expected to result in harmful health effects.

Multiple Chemical Exposures

Several studies, among them studies by the National Toxicology Program in the United States and the TNO Nutrition and Food Research Institute in the Netherlands, generally support the conclusion that if each individual chemical is at a concentration not likely to produce harmful health effects, exposures to multiple chemicals are also not expected to be of health concern (for reviews, see Seed et al. 1995; Feron et al. 1993). In addition, several animal and human studies (Berman et al. 1992; Caprino et al. 1983; Harris et al. 1984) have reported thresholds for interactions, and Jonker et al. (1990) and Groten et al. (1991) demonstrated the absence of interactions at doses 10-fold or more below effect thresholds.

That said, the estimated exposure doses for people eating fish and shellfish from Pearl Harbor *approach* levels that have been shown to cause measurable changes (decreased antibody response) in female Rhesus monkeys chronically exposed to Aroclor 1254 (Arnold et al. 1993; Tryphonas et al. 1989, 1991). Therefore, it would be prudent public health practice to limit consumption of fish and crabs from Pearl Harbor.

Table B-1. Parameters Used in the Exposure Dose Calculations for PHNC

	Soil			***Fish Fillet and Whole Body***	***Crab Whole Body***	***Sediment***
	Waipahu Ash Landfill	***Former Pesticide Mixing Plant***	***Waipio Peninsula, Transformer Site W-11***			
Ingestion Rate ■ Adult ■ Child	0.0001 kg/day 0.0002 kg/day			0.085 kg/day 0.034 kg/day	0.024 kg/day 0.009 kg/day	0.00005 kg/day 0.0001 kg/day
Exposure Frequency ■ Adult ■ Child	8.7 days/year 8.7 days/year	52 days/year 52 days/year		365 days/year 365 days/year		
Exposure Duration ■ Adult ■ Child	11 years 6 years	30 years 6 years	6 years (late teen) 6 years	70 years 6 years		
Body Weight ■ Adult ■ Child	70 kg 16 kg					
Averaging Time ■ Adult ■ Child	365 days/year×11 years 365 days/year×6 years	365 days/year×30 years 365 days/year×6 years	365 days/year×6 years (late teen) 365 days/year×6 years	365 days/year×70 years 365 days/year×6 years		

Estimated exposure dose = concentration × ingestion rate × exposure frequency × exposure duration / body weight × averaging time

kg kilogram

Table B-2. Estimated Exposure Doses from Ingestion of the Average Concentration Detected in Pearl Harbor Fish and Crabs

Chemical	Sample	Average Concentration (mg/kg)	Exposure Doses (mg/kg/day)		Noncancer Health Guideline (mg/kg/day)	Cancer Slope Factor (mg/kg/day)-1	Cancer Risk
			Adult	Child			
Metals							
Antimony	Fish fillet	0.22	2.7E-04	4.7E-04	4.0E-04	Not available	
	Whole fish	0.14	1.7E-04	3.0E-04			
	Whole crab	Not detected					
Total Arsenic	Fish fillet	0.25	3.0E-04	5.3E-04	3.0E-04	1.5	4.5E-04
	Whole fish	0.71	8.6E-04	1.5E-03			1.3E-03
	Whole crab	3.4	1.2E-03	1.9E-03			1.8E-03
Inorganic Arsenic*	Fish fillet	0.25	6.0E-05	1.1E-04	3.0E-04	1.5	9.0E-05
	Whole fish	0.71	1.7E-04	3.0E-04			2.6E-04
	Whole crab	3.4	2.3E-04	3.8E-04			3.5E-04
Chromium	Fish fillet	0.06	7.0E-05	1.2E-04	3.0E-03	Not available	
	Whole fish	2.5	3.0E-03	5.2E-03			
	Whole crab	0.66	2.3E-04	3.7E-04			
Copper	Fish fillet	Not detected			2.0E-02	Not available	
	Whole fish	16	1.9E-02	3.4E-02			
	Whole crab	24	8.3E-03	1.4E-02			
Iron	Fish fillet	Not detected			3.0E-01	Not available	
	Whole fish	945	1.1E+00	2.0E+00			
	Whole crab	240	8.2E-02	1.3E-01			
Pesticides							
Dieldrin	Fish fillet	0.0059	7.1E-06	1.2E-05	5.0E-05	16	1.1E-04
	Whole fish	0.0131	1.6E-05	2.8E-05			2.5E-04
	Whole crab	0.0014	4.8E-07	7.9E-07			7.7E-06
Herbicides							
MCPP	Fish fillet	Not sampled			1.0E-03	Not available	
	Whole fish	31	3.8E-02	6.6E-02			
	Whole crab	Not detected					
Ordnance-Related Compounds							
2,4,6-Trinitrotoluene	Fish fillet	Not sampled			5.0E-04	0.03	Not sampled
	Whole fish	0.2483	3.0E-04	5.3E-04			9.0E-06
	Whole crab	0.036	1.2E-05	2.0E-05			3.7E-07
Dioxins/Furans							
Dioxin TEQ†	Fish fillet	5.9E-07	7.2E-10	1.3E-09	1.0E-09	150,000	1.1E-04
	Whole fish	6.4E-07	7.7E-10	1.4E-09			1.2E-04
	Whole crab	5.0E-06	1.7E-09	2.8E-09			2.6E-04

Table B-2. Estimated Exposure Doses From Ingestion of the Average Concentration Detected in Pearl Harbor Fish and Crabs (continued)

Chemical	Sample	Average Concentration (mg/kg)	Exposure Doses (mg/kg/day)		Noncancer Health Guideline (mg/kg/day)	Cancer Slope Factor (mg/kg/day)-1	Cancer Risk
			Adult	Child			
Polychlorinated Biphenyls							
Total PCBs‡	Fish fillet	0.15	1.8E-04	3.2E-04	2.0E-05	2	3.7E-04
	Whole fish	0.31	3.8E-04	6.7E-04			7.6E-04
	Whole crab	0.047	1.6E-05	2.7E-05			3.3E-05
Aroclor PCBs§	Fish fillet	0.073	8.9E-05	1.6E-04	2.0E-05	2	1.8E-04
	Whole fish	0.12	1.5E-04	2.6E-04			3.0E-04
	Whole crab	0.033	1.1E-05	1.8E-05			2.2E-05

Bold text indicates that the exposure dose and/or the cancer risk exceeded the health guideline for that chemical.
Only chemicals with exposure doses that exceeded health guidelines are included in this table.

* ATSDR assumed that 20 percent of the total arsenic detected was inorganic arsenic.
† Total relative concentrations were calculated using the toxic equivalency factor approach for dioxins.
‡ Estimate of total PCBs calculated as 2 times the sum of detect values for 18 congeners (8, 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, 209). The Navy used this method for estimating total PCBs from congener data, which is also the method used by the National Oceanic and Atmospheric Administration's Status and Trends Program.
§ Estimate of total PCBs for an Aroclor-equivalent value, determined from the distribution of congeners in the sample.

MCPP 2-(2-methyl-4-chlorophenoxy) propionic acid
mg/kg milligrams per kilogram
mg/kg/day milligrams per kilogram per day
TEQ toxic equivalent

Table B-3. Chemicals Detected Above Comparison Values in Pearl Harbor Sediments

Chemical	*Minimum Concentration (mg/kg)*	*Maximum Concentration (mg/kg)*	*Average Concentration (mg/kg)*	*Percent Detected*	*CV (mg/kg)*	*CV Type*
Metals						
Arsenic	4.2	66.9	15	100%	0.5	CREG
Chromium	10	391	152	100%	200	RMEG (chromium VI)
Copper	8.4	2,020	175	100%	1,000	IEMEG
Iron	4,680	160,000	60,672	100%	23,000	RBC
Lead	1.1	705	71	100%	400	SSL
Butyltins						
Tributyltin	0.0042	0.085	0.0067	18%	See Table B-4.	
Polycyclic Aromatic Hydrocarbons						
Benz(a)anthracene	0.0018	20	0.38	99%	0.87	RBC
Benzo(a)pyrene	0.0019	47	0.76	100%	0.1	CREG
Benzo(e)pyrene	0.0025	38	0.55	99%	0.1	CREG
Benzo(b)fluoranthene	0.0018	73	1.00	100%	0.87	RBC
Benzo(k)fluoranthene	0.0026	43	0.91	77%	8.7	RBC
Dibenz(a,h)anthracene	0.0018	15	0.19	93%	0.087	RBC
Indeno(1,2,3-cd)pyrene	0.0019	28	0.43	99%	0.87	RBC
1-Methylphenanthrene	0.0016	1.1	0.029	68%	0.087	RBC (dibenzo(a,h)anthracene)
Perylene	0.0018	12	0.19	97%	0.1	CREG (benzo(a)pyrene)
Pesticides						
Dieldrin	0.00016	0.09	0.0029	56%	0.04	CREG
Dioxins/Furans						
Dioxins were evaluated during the second level of screening. See Table B-4.						
Polychlorinated Biphenyls						
PCBs were evaluated during the second level of screening. See Table B-4.						

Chemicals with maximum concentrations that exceeded comparison values are included in this table.

CREG	cancer risk evaluation guide
CV	comparison value
IEMEG	intermediate environmental media evaluation guide
mg/kg	milligrams per kilogram
RBC	risk-based concentration
SSL	soil screening level

Table B-4. Estimated Exposure Doses From Incidental Ingestion of the Average Concentration Detected in Pearl Harbor Sediments

Chemical	*Average Concentration (mg/kg)*	*Exposure Doses (mg/kg/day)*		*Noncancer Health Guideline (mg/kg/day)*	*Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Cancer Risk*
		Adult	*Child*			
Metals						
Arsenic	15	1.0E-05	9.2E-05	0.0003	1.5	1.6E-05
Chromium	152	1.1E-04	9.5E-04	0.003	Not available	
Copper	175	1.3E-04	1.1E-03	0.02	Not available	
Iron	60,672	4.3E-02	3.8E-01	0.3	Not available	
Lead	71	5.1E-05	4.4E-04	0.02	Not available	
Butyltins						
Tributyltin	0.0067	4.8E-09	4.2E-08	0.00003	Not available	
Polycyclic Aromatic Hydrocarbons						
Benz(a)anthracene	0.38	2.7E-07	2.4E-06	NA	0.73	2.0E-07
Benzo(a)pyrene	0.76	5.4E-07	4.7E-06	NA	7.3	3.9E-06
Benzo(b)fluoranthene	1.00	7.1E-07	6.2E-06	NA	0.73	5.2E-07
Benzo(e)pyrene	0.55	3.9E-07	3.4E-06	NA	7.3	2.9E-06
Benzo(k)fluoranthene	0.91	6.5E-07	5.7E-06	NA	0.073	4.8E-08
Dibenz(a,h)anthracene	0.19	1.4E-07	1.2E-06	NA	7.3	1.0E-06
Indeno(1,2,3-cd)pyrene	0.43	3.1E-07	2.7E-06	NA	0.73	2.2E-07
1-Methylphenanthrene	0.029	2.1E-08	1.8E-07	NA	7.3	1.5E-07
Perylene	0.19	1.3E-07	1.2E-06	NA	7.3	9.7E-07
Pesticides						
Dieldrin	0.0029	2.1E-09	1.8E-08	0.00005	16	3.3E-08
Dioxins/Furans						
Dioxin TEQ*	3.7E-05	2.6E-11	2.3E-10	1E-09	150,000	4.0E-06
Polychlorinated Biphenyls						
Total PCBs	0.13	9.5E-08	8.3E-07	0.00002	2	1.9E-07
Aroclor PCBs	0.20	1.4E-07	1.2E-06	0.00002	2	2.8E-07

Bold text indicates that the exposure dose and/or the cancer risk exceeded the health guideline for that chemical.

* Total relative concentrations were calculated using the toxic equivalency factor approach for dioxins.

mg/kg milligrams per kilogram
mg/kg/day milligrams per kilogram per day
NA not available
TEQ toxic equivalent

Appendix C. Chemical Contamination of Fish and Crab from Pearl Harbor

Hawai'i Department of Health

The Health State

CHEMICAL CONTAMINATION OF FISH AND CRAB FROM PEARL HARBOR

Fish are an important part of a healthy diet. They are a lean, low-calorie source of protein. However, fish caught in Pearl Harbor may contain chemicals that pose a health risk if these fish are eaten in large amounts, especially over long periods of time. To ensure your good health, the Hawaii Department of Health is advising against eating fish which were caught in Pearl Harbor.

Why has DOH issued a fish advisory for Pearl Harbor?

Hawaii DOH is recommending that people not eat fish or shellfish from Pearl Harbor to prevent possible health effects from long term exposure. Recent samples collected by the Navy found elevated levels of PCBs, several organochlorine pesticides and the herbicide mecoprop (MCPP) in whole fish, fish fillets and crab.

The fish advisory is based on preventing cancer and noncancer health effects in children and adults from eating fish contaminated with PCBs and certain pesticides from Pearl Harbor. Eating a single large meal or a few such meals of fish from Pearl Harbor should not make you ill. However, continuous exposure over many years may be a health concern in some individuals.

What are the health risks of eating contaminated fish from Pearl Harbor?

In general, the health effects from eating fish from Pearl Harbor depend upon the concentration of hazardous substances in the fish tissue, how much fish is eaten, how long has fish been eaten from the harbor as well as a person's age, sex, diet, family traits, lifestyle and overall state of health. Overall, PCBs were found to pose the most significant health threat of all the chemicals detected in the Navy study.

Eating contaminated fish regularly can cause PCBs to build up in your body. It may take years of regularly eating contaminated fish to build up to amounts that are a health concern. High risk groups such as pregnant women, nursing mothers, women who are planning a pregnancy and children are especially sensitive to PCBs, and should not eat any fish from Pearl Harbor.

Exposure to PCBs is linked to developmental problems in children whose mothers were exposed to PCBs before becoming pregnant. PCBs also cause changes in blood, liver and immune function in adults. They have also been shown to cause cancer in laboratory animals and may cause cancer in humans. Your risk of cancer from eating contaminated fish or shellfish from Pearl Harbor cannot be predicted with certainty. At the PCB levels found in fish and crab in Pearl Harbor, a single large meal, or a few such meals, should not make you ill. Frequent eating of PCB-contaminated fish over a period of years may lead to the buildup of PCBs in your body to levels that could affect your health. Although this might not lead to a distinct illness, prevention is the best remedy. DOH recommends that you avoid eating fish from Pearl Harbor to prevent PCBs and other compounds from building up to unsafe levels in your body.

Where do the contaminants come from and how did they get into fish?

Although PCBs and the organochlorine pesticides are no longer made in the United States, people can still be exposed to them. PCBs were used extensively in transformers, capacitors and other electrical equipment. The organochlorine pesticides found in fish and crabs were used to kill termites and other insects. A wide variety of human activities along the shoreline and upland drainage basins are likely sources of the pollutants found in sediments and marine organisms.

These compounds persist in the environment for a long time. Usually they stick to soil or sediments and may remain there for years. PCBs and the organochlorine pesticides enter the bodies of fish from water, sediment and food that have been contaminated with these compounds. These chemicals build up in the fat of fish and can reach levels many times higher than the levels in water or sediments.

Are all fish from Pearl Harbor contaminated with PCBs and pesticides?

The Navy study sampled tilapia, goatfish, mullet and crab. These marine species were selected for several reasons: 1) they are bottom feeders and more highly exposed to the contaminated sediments; 2) they are readily collectable and available throughout the harbor; and 3) they are species that are likely to be consumed by the public. We do not know whether all fish species from Pearl Harbor contain PCBs and pesticides at levels that could pose a health risk. In general, larger, older fish may be more contaminated than younger, smaller fish. Contaminants build up in large predators and bottom-feeding fish more rapidly than in other species. As precautionary measure, DOH recommends avoiding eating all fish and shellfish from Pearl Harbor.

What should I do if I have been eating fish from Pearl Harbor?

At the PCB levels measured by the Navy in fish and crab from Pearl Harbor, we would not expect you to become ill from a single large meal or a few fish meals. Even if you ate contaminated fish over a period of years you might not develop any illness. This does not mean you should not be concerned. We know that PCBs build up in the body over time and that exposure to higher levels of PCBs in fish can cause health effects in children. Additionally, your risk of cancer increases after many years of exposure.

If you have been eating large amounts of fish from Pearl Harbor for many years you may be at a higher risk for cancer or other diseases. For that reason we recommend that you stop eating fish from Pearl Harbor (the PCBs and other contaminants can slowly clear from your body and lessen your risk). In addition, we recommend the following to enhance your overall health: 1) maintain a healthy lifestyle - get regular exercise; eat a balanced and nutritious diet including fish from uncontaminated waters; moderate your alcohol intake if you drink; and, if you smoke, try to quit; 2) get regular medical checkups for yourself and your family; 3) minimize stress as much as possible.

The chemicals that you are exposed to in your environment can increase your risk of certain illnesses, but they are only one of many important lifestyle factors affecting your overall health status, and you have control over many of the others.

The Health State

Appendix D. Responses to Public Comments

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments during the public comment period (August 2, 2005 to September 19, 2005) for the Pearl Harbor Naval Complex (PHNC) Public Health Assessment. The table below shows both the comments and how they were addressed. The list does not include editorial comments.

	Comment	How Addressed
1	Page 12, "How does ATSDR evaluate potential exposures": The text summarizes the steps used to evaluate potential exposures. As stated, ATSDR calculates (derives) an exposure dose for chemicals that exceed their specified screening value. The bottom of page 12 concludes that the exposure doses are compared against health based guidelines. The top of page 13 begins with a discussion on toxicity. It is unclear what actions ATSDR will take if the exposure dose is less than or exceeds the health based guidelines. It is not until Appendix B that the comparison of dose to comparison values is discussed. We suggest briefly describing what actions are taken after the dose is compared to the reference value in the discussion on page 12.	ATSDR added the following language to page 12–13: "If estimated doses are higher than the health guideline values, ATSDR further examined the chemical-specific health effect levels discussed in the scientific literature and more fully reviewed exposure potential."
2	Page 23 and 24: The frequency of detection presented in Table 3 for 2, 4-dichlorophenoxyacetic acid and 2, 4, 5-trichlorophenoxyacetic acid is less than 5 percent. The potential estimated dose for the two chemicals is presented on page 24. Normally, chemicals detected less than 5 percent are removed as chemicals of potential concern. We suggest removing 2, 4-DB and 2, 4, 5-TP from the list of chemicals of potential concern. Therefore, there would not be a need to calculate an estimated dose.	ATSDR removed 2,4-D, 2,4,5-TP, and 2,4-DB from Table 3 and the following paragraph.
3	Page 22 and 26, Appendix B: The text states the maximum concentration is used in the assessment of the Former Pesticide Mixing Area and the average concentration is used in the assessment of Waipio Peninsula Transformer Site W-11. The estimated exposure dose Tables in Appendix B state the average concentration was used in the exposure calculations. The reasons for using the average concentration instead of the maximum concentration should be discussed. We recommend ATSDR use the 95% UCL of the mean when calculating dose estimates and the maximum concentration during the initial screening.	ATSDR recognizes the importance of using the 95% UCL for risk assessments, but the goal of a public health assessment is to quantify an exposure to the extent that it can be qualitatively evaluated with respect to the available toxicological information. Initially, the maximum concentrations were used to estimate exposure because they provided a rapid and conservative evaluation. Because the results of the calculated exposure were above CVs, the analysis was refined to look at estimated exposure to the average concentration of the samples most representative of the environmental media. For the evaluations at the Waipio Peninsula Transformer Site W-11, this resulted in a relatively small number of soil samples that may not provide an accurate statistical analysis. The average concentrations were combined with the conservative exposure parameters to estimate exposure for comparison with the toxicological information. ATSDR added language to Appendix B to justify the use of average concentrations (see page B-4, B-5, and B-16).

	Comment	How Addressed
4	Appendix B, "Overview of ATSDR's Methodology for Evaluating Potential Public Health Effects": The exposure parameters used in the dose calculations are listed within the text throughout the report. They are not listed within the appendix. For ease of understanding, we recommend including a Table in the Appendix containing all of the exposure parameters used in calculating the dose for each pathway.	ATSDR added Table B-1 with the exposure parameters.
5	Appendix B, Page B-2 and B-3, "Comparing Estimated Dose to Health Guideline Values": The last paragraph explains how MRLs and RfDs are developed and their role as a comparison to the calculated dose. The top of page B-3 discusses, "In addition" the screening for cancer effects. The differences between calculating an intake exposure and comparing to a reference dose (Non –carcinogenic) and multiplying a calculated exposure dose by a slope factor (carcinogenic effects) may be a difficult concept for the average reader. We suggest separating the discussion into separate sub-headings for non carcinogen and carcinogens.	ATSDR added the title "Estimating Cancer Risk."
6	Appendix B, Page B-2 and B-3, "Comparing Estimated Dose to Health Guideline Values": There is no discussion concerning adding exposure risk of separate chemical into a cumulative risk. The appendix should include a discussion on how ATSDR evaluates exposure to multiple chemicals.	ATSDR added a discussion of multiple chemical exposures to page B-18.
7	Appendix B, Page B-16, "Dermal Exposure to Pearl Harbor Sediments": Estimated exposure doses from dermal exposures to Pearl Harbor Sediments are not provided. Dermal exposures to chemicals detected above comparison values should be included in the public health assessment.	ATSDR generally considers that for most exposure scenarios dermal exposure to be a minor contributor to the overall exposure dose relative to the contributions of ingestion and inhalation exposures. Therefore, ATSDR does not evaluate dermal exposures quantitatively. ATSDR adjusted the language on page B-18.