PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM
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LIST OF ABBREVIATIONS

ABW	Air Base Wing
AFB	Air Force Base
AOC	area of concern
ATSDR	Agency for Toxic Substances and Disease Registry
CAIS	chemical agent identification sets
CCl_4	carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRP	community response plan
CV	comparison value
DCA	1,2-dichloroethane
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ESI	Expanded Source Investigation
FFA	Federal Facility Agreement
FS	feasibility study
GEPA	Guam Environmental Protection Agency
GPZ	groundwater protection zone
GWA	Public Utility Agency of Guam
IRP	Installation Restoration Program
kg	kilogram
MARBO	Marianas Bonins Command
MCL	EPA's maximum contaminant level
mg/kg/day	milligrams per kilogram per day
MRL	ATSDR's minimal risk level

MW	military well
NA	not applicable
ND	not detected
NPL	EPA's National Priorities List
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
pCi/L	picocuries per liter
PHAP	public health action plan
POL	petroleum, oil, and lubricants
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RfD	EPA's reference dose
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision (ROD)
SDS	storm drainage system
SVOC	semi-volatile organic compound
TCA	1,1,1-trichloroethane
TCE	trichloroethylene
TPH	total petroleum hydrocarbons
UST	underground storage tank
UXO	unexploded ordnance
VOC	volatile organic compound
WDBP	War Dog Borrow Pit

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YIGO, GUAM

SUMMARY

Andersen Air Force Base (Andersen AFB) is located in northern Guam in the Southwest Pacific. Established during World War II, Andersen AFB has provided 50 years of military support services, including vehicle maintenance, fuel storage, ammunition stockpiling, and explosive ordinance disposal. Base activities have resulted in numerous fuel, pesticide, and chemical spills.

Contamination has been identified at several areas of Andersen AFB, including at landfills, waste piles, and chemical storage areas. Most of the areas are currently in the investigation stages of the Department of Defense's Installation Restoration Program (IRP), but some remediation activities have been planned and/or conducted.

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted its initial site visit of the base in 1993. Follow-up ATSDR site visits were conducted in January 1999 and May 2000. During these site visits, the following potential exposure pathways were identified:

1. Ingestion of contaminated on- and off-site groundwater

2. Consumption of contaminated local biota (plants or animals)

3. Dermal contact with and incidental ingestion of contaminated soil

4. Exposure to radon in the base-housing units

5. Encounters with physical hazards, such as unexploded ordnance.

Using available data, this public health assessment evaluates public health concerns associated with these five potential exposure pathways at Andersen AFB, as well as other community concerns.

Exposure to Contaminated Groundwater

Parts of Andersen AFB overlie Guam's sole-source aquifer in the Groundwater Protection Zone, an area which supplies over 70% of the island's population with drinking water. During IRP

investigations, groundwater underlying Andersen AFB was found to be contaminated with volatile organic compounds (VOCs). VOCs at levels above ATSDR's health-based comparison values and EPA Safe Drinking Water Standards were also found in three base production wells. (These VOCs included tricholorethylene--also called TCE--and tetrachloroethylene.) Other active drinking water base production wells are either upgradient of or some distance away from areas of contamination. ATSDR evaluated past exposure to contaminants in the affected production wells and determined that drinking this water would not harm individuals or increase their likelihood of developing adverse health effects.

ATSDR does not expect any public health hazards--now or in the future--for individuals drinking water from the Andersen AFB water supply or any other production wells on Guam. There are several reasons for this. First, the military's remediation actions are further reducing contamination at the base. Second, the natural groundwater flow patterns dilute chemical contaminants to concentrations well below levels of public health concern. Finally, mixing of drinking water in the base's distribution system further dilutes the levels of any contaminants in the water before the water reaches the taps.

Exposure to Contaminated Biota

Several on- and off-base biota samples were collected and analyzed for potential contamination. These included samples from Sambar deer, wild pig, monitor lizard, brown tree snake, and papaya. Data are limited, but using available information, ATSDR compared contaminant levels in Guam biota to acceptable background concentrations and/or exposure screening values. Only arsenic and aluminum in the sampled biota warranted further investigation. Due to the highly conservative nature of ATSDR's evaluation process and the uncertainties surrounding the evidence for arsenic and aluminum toxicity at such low levels of environmental exposure, ATSDR concludes that the consumption of local biota poses no public health hazard.

Exposure to Contaminated Soil

Military practices have potentially affected soil at many areas of Andersen AFB. There is, however, minimal (if any) public exposure to contaminated on-site soils, because contamination occurs in restricted access areas and often lies in subsurface soils. Therefore, ATSDR concludes that no apparent public health hazards are associated with soil contamination at Andersen AFB.

To prevent potential future exposures from contaminated soil at the base, the Air Force is conducting remedial actions overseen by the U.S. Environmental Protection Agency (EPA) and the Guam Environmental Protection Agency (GEPA). In the future, certain areas will be returned to the government of Guam for public use; some of this property may have institutional controls and/or deed restrictions to limit future uses or to guide future development.

Exposure to Radon

Guam's radon levels are naturally high. Radon levels are not caused or elevated by military practices associated with Andersen AFB. On-site military housing, however, has been affected by radon. Since monitoring began in 1987, radon has been detected in certain base housing at levels above EPA's recommended action level of 4 picocuries per liter (pCi/L) of air. Some units contained radon levels

above 120 pCi/L. Beginning in 1989, aggressive remediation efforts began mitigating all known radon contamination on base. In 1993, however, an earthquake struck Guam and disrupted the Air Force's radon mitigation efforts. As of May 2000, 755 of the 1,390 housing units on base have been renovated to reduce/prevent potential radon contamination.

Increased risk of lung cancer is the primary health concern associated with radon exposure, but several factors, such as length of exposure, concentration of radon, and smoking history, influence an individual's likelihood of developing the disease.

Judging from available information, ATSDR concludes that the full extent of past exposure to radon is unknown; therefore, the associated hazards remain uncertain. Most people living in housing at the base would have been exposed for only a relatively short period of time (the usual stay at Andersen AFB is 2 years) and to levels below 20 pCi/L. Radon mitigation efforts have reduced radon levels in housing. The Air Force is currently evaluating its radon program to ensure that they have adequately sampled, mitigated, and re-sampled all on-site structures as necessary given current environmental conditions.

Physical Hazards

Unexploded ordnance (UXO) has been disposed of at several locations in the Northwest Field. The Northwest Field is restricted to public access, but certain areas are open to hunters with permits. Although remote, an encounter with a UXO item could possibly occur in the Northwest field. The probability of a hazardous encounter has been reduced through the current educational program and access restrictions at Andersen. No accidents involving UXO have been reported to date. Historical data suggest that the probability of an encounter resulting in detonation is limited to instances where the UXO is actively disturbed, such as being picked up and tampered with or dug into during excavation. It is unlikely that a harmful outcome would occur during an accidental encounter. *If UXO is discovered do not touch or tamper with it. Contact the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198.*

Table 1. Exposure Hazards Summary Table--Andersen Air Force Base, Guam

Exposure Scenario	Time Frame	Exposure Yes/No	Hazard	Actions Taken/Recommended
Exposure to *groundwater* contaminants through on-site military wells	Past Current Future	Past: limited Current and Future: no	Past: no apparent public health hazard Current and future: no public health hazard	Elevated levels of TCE and PCE were found in MW-1, MW-2, and the Tumon-Maui well. The Air Force installed air stripping towers to treat water from MW-2 and the Tumon-Maui well. The MW-2 and the Tumon-Maui well are closed due to calcification of the air stripping towers.
Exposure to *groundwater* contaminants through off-site municipal and private wells	Past Current Future	Past: no Current: no Future: no	No apparent public health hazard	No off-base wells have been affected. Groundwater underlying much of Andersen AFB is protected by groundwater protection zone regulations and restrictions.
Consumption of	Past	Past:	No apparent	The Air Force and GEPA have conducted tissue sample

locally harvested or locally caught *biota* from Andersen AFB	Current Future	minimal Current: minimal Future: minimal	public health hazard	analysis of Andersen AFB biota. Contaminant concentration levels and estimated public exposure doses are below levels of human health concern.
Contact with contaminated *soil* at Andersen AFB	Past Current Future	Past: limited Current: limited Future: limited	No apparent public health hazard	Base security limits public access to IRP sites, where soil contamination has been detected. Contaminated soil has been removed from certain areas of the base. Deed restrictions will accompany future land transfers.
Exposure to naturally occurring *radon* in on-site housing and other buildings	Past Current Future	Past: yes Current: limited Future: limited	Past and current: no apparent public health hazard Future: no apparent public health hazard	The Air Force has monitored and mitigated radon levels in on-site housing since 1987. An earthquake interrupted mitigation efforts in 1993, but the Air Force conducted more radon sampling in 1998 and plans to expand its mitigation efforts in 2001 to affected buildings.
Physical hazards: unexploded ordnance and exposed asphalt debris	Past Current Future	Past: no Current: minimal Future: minimal	Past: no apparent public health hazard Current and future: no apparent public health hazard	There have been no accidents or incidents involving unexploded ordnance. Education and UXO awareness program is in place. Area restrictions are communicated to recreational users. Exposed asphalt debris and tar lagoon is in restricted area awaiting disposal.
Key: AFB = Air Force Base; GEPA = Guam Environmental Protection Agency; IRP = Installation Restoration Program; MW = military well; PCE = tetrachloroethylene; TCE = trichloroethylene				

BACKGROUND

Site Description and History

Andersen Air Force Base (Andersen AFB) is made up of several parcels of land situated on the northern end of Guam, an unincorporated island territory of the United States. Guam, the largest and most southern island of the Marianas Island group, is located in the southwest Pacific Ocean. Guam's landmass, about 30 miles long and 4 to 12 miles wide, covers approximately 209 square miles (USAF 1992a).

Andersen AFB covers approximately 24.5 square miles. It consists of two major areas and several smaller areas, called annexes (see Figure 1). The major areas, collectively known as "the main base," are North Field, containing the base's active operations, and Northwest Field, containing abandoned runways and landing fields. The annexes are scattered throughout northern Guam and contain base housing, communications services, and water and petroleum storage facilities. The two largest annexes

are the Marianas Bonins Command (MARBO) Annex (also known as Andersen South) and the Harmon Annex. The MARBO Annex lies about 4 miles south of the main base and covers approximately 3.8 square miles. The Harmon Annex, 4 miles south of Northwest Field, covers about 1,817 acres in western Guam. Both the MARBO and Harmon annexes are largely deserted and covered with brush (USAF 1993; SAIC 1991).

During World War II, the U.S. Army Air Corps built and maintained three air bases on the island: North Field, a B-29 bomber facility; Northwest Field, a fighter-plane base; and Harmon Field, an aircraft depot and maintenance base. During this time of rapid military growth, the Air Force disposed of some wastes (of unknown type) on private lands adjacent to Andersen AFB. After World War II, large quantities of war materials and left-over equipment (e.g., ammunition, artillery, and vehicles) were disposed of at Andersen AFB. Harmon Annex and Northwest Field closed soon after the war ended, but the rest of the base continued to be used for ongoing Air Force activities, including logistical and military support during the Korean and Vietnam Wars (USAF 1992a, 1993).

During the decades of military use, chemicals were used and stored in various locations on the base and spilled during routine aircraft, vehicle, and ground maintenance operations. Wastes from military and housing operations were buried in two landfills at the south end of the North Field runways from 1946 to the late 1970s. Soil and groundwater beneath these landfills, and in dozens of other areas on base, may have been contaminated over the years by routine waste disposal, miliary operations, and occasional fuel spills. Ten acres in the North Field area still serve as a sanitary landfill for Andersen AFB's non-hazardous waste. Hazardous waste is now disposed of off site in compliance with federal law (USAF 1992a; SAIC 1991).

Today, Andersen AFB is home to the Pacific Air Force's 13th and 36th Air Base Wing (ABW), Air Mobility Command's 634th Air Mobility Support Squadron, and several other special organizations. The 36th ABW is the host unit. With huge fuel and munitions storage facilities and dual 2-mile-long runways, Andersen AFB is an important forward-based logistics-support center for exercise and contingency forces deploying throughout the Southwest Pacific and Indian Ocean area. The wing is composed of the 36th Support Group, the 36th Logistics Group, the 36th Medical Group, and the 36th Operations Support Squadron. These squadrons and branches provide special services, including fuel storage, liquid oxygen production, ammunition stockpiling, and explosive ordinance disposal (USAF 1993, 2001). Public access to Andersen AFB is restricted by perimeter fencing and military security.

The U.S. Department of Defense (DOD) plans to return 3,500 acres of military land (containing some Andersen AFB acreage, as well as U.S. Navy property, and referred to as "excess land") to the government of Guam for public use (USAF 1993). The specific sizes and locations of these parcels have not been determined. For the purpose of this public health assessment, the Agency for Toxic Substances and Disease Registry (ATSDR) has assumed that public access to these military areas will remain restricted. ATSDR will re-evaluate potential exposure pathways and public health implications if and when land use changes.

Remedial and Regulatory History

During the 1970s, Andersen AFB began monitoring its nine water supply wells on a monthly basis. Results of the sampling indicated that chemicals, including solvents, pesticides, fuel products, and

some metals, had entered certain water supply wells (Williams 1993; SAIC 1991). Under the DOD Installation Restoration Program (IRP), Andersen AFB then began a Phase I study in 1983 to track the history of the use and disposal of materials on the base. Using the results of this records search, Andersen AFB identified several areas around the base where chemicals may have spilled, leaked, or been stored or disposed of. The areas included fire training areas, chemical storage areas, and landfills. As soil and groundwater samples were collected and analyzed, Andersen AFB determined that some of the sites required further investigation. In early 1985, Andersen AFB made recommendations for Phase II field investigations (USAF 1996).

The IRP Phase II was divided into two parts, Stage 1 and Stage 2. Twenty IRP sites were investigated during the IRP Phase II, Stage 1, investigation. Eleven of those sites and four additional sites were investigated during the IRP Phase II, Stage 2, investigation. The Stage 1 investigation confirmed and quantified contamination levels, and Stage 2 was a remedial investigation/feasibility study (RI/FS). During both stages, groundwater, surface soil, subsurface soil, and soil gas field-sampling data were collected. Results indicated that the principal site contaminants are trichloroethylene (TCE), tetrachloroethylene (PCE), pesticides, fuel products, and some metals. Most of the contamination reportedly is contained within Andersen AFB property, although some chemicals migrate off base via groundwater and biota pathways or may exist at off-base locations proposed for further investigations (SAIC 1991).

Independent of IRP Phase II efforts, the Guam Environmental Protection Agency (GEPA) developed a program on Guam in 1986 to prevent contamination from entering the groundwater and to preserve the quality of groundwater now and in the future (SAIC 1991; Earth Tech 1998). The program, which identifies vulnerabilities and restricts uses, established:

1. A groundwater protection zone (GPZ)--a boundary intended to preserve groundwater quality--approximately 4,000 feet from the shoreline.

2. Subbasin boundaries, which are designated island boundaries that contain groupings of well heads.

3. Core areas, which are 1,000-foot areas around wells that are protected from any kind of development or use.

All areas within the GPZ overlie existing or future groundwater development sites or provide recharge waters to potential drinking water sources. Some Andersen AFB property lies within the GPZ boundaries.

Andersen AFB was placed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) on October 14, 1992, due to the extent of groundwater contamination under the base (USAF 1992b). The NPL is part of EPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund. The Air Force entered

into a Federal Facility Agreement (FFA) with EPA Region IX and GEPA on March 30, 1993 (USAF 1992a, 1997). EPA and GEPA share responsibilities in overseeing environmental investigations and cleanup at Andersen AFB. The FFA outlined a comprehensive strategy for environmental restoration of Andersen AFB and identified the underlying groundwater aquifer and 50 sites on Andersen AFB property where hazardous materials may have been disposed of, spilled, or stored. These 50 sites were later reorganized to create a total of 39 sites scheduled for further RI/FS activities (USAF 1996). All IRP sites have been posted with signs to warn anyone approaching the areas, and several areas are fenced or are located in areas of restricted access (e.g., the Andersen AFB Landfill Complex).

To guide RI/FS activities at Andersen AFB, the FFA defines a comprehensive operable unit (OU) strategy. The OU strategy grouped previously identified IRP sites that share similar environmental media and geographic distributions, and assigned each site to one of six OUs. In July 1996, these six OUs were reorganized into four OUs based on geographic locations. The new OUs are the Main Base OU (23 IRP sites), Northwest Field OU (7 IRP sites plus 1 proposed site), MARBO Annex OU (6 IRP sites), and Harmon Annex OU (3 IRP sites). The sites included in each OU are described in Appendix A.

The Air Force is at varying stages of investigation at each of the 39 IRP sites. To date, a RI/FS has been completed at each of the six IRP sites within the MARBO Annex, and a Record of Decision (ROD) signed in April 1998 explains which clean-up alternative will be used as needed for soil and groundwater at each IRP site. Remedial investigations are still underway at 3 sites in the Northwest OU and at 10 sites at the Main Base, while engineering evaluations/cost analyses have been completed for the 3 sites at the Harmon OU, 4 sites at the Northwest Field OU, and 9 sites in the Main Base OU (USAF 2000). (See Appendix A for a further description of activities at each IRP site.)

The Air Force completed an Expanded Source Investigation (ESI) that involved conducting a records search and visual site inspections. The preliminary ESI identified 53 areas of concern (AOCs) that did not fall under the CERCLA RI/FS, but that warranted further investigation (USAF 2000). Through environmental baseline surveys at AOCs located at the Harmon Annex, Camp Edusa, the Andersen Radio Beacon Annex, the Harmon POL Storage Annex No. 1 ("POL" stands for petroleum, oil, and lubricants), and the Andersen South Administrative Annex, it was determined that 44 AOCs warrant no further action, while 9 AOCs require limited remediation.

Andersen AFB also investigated if there were any off-base, private property areas containing chemicals of concern in the soil from past military practices. The only such areas are the Urunao dump sites, which lie on the boundary of the Northwest Field OU. The dump sites are collectively being proposed as IRP 40 (USAF 2000).

ATSDR Activities

In February 1993, ATSDR conducted a site visit at Andersen AFB. ATSDR examined 36 of the 39 study areas. Past exposure to TCE in groundwater and radon in base housing units were identified as potential public health hazards. In addition, there was a concern that the wild pig and deer populations on Andersen AFB may be a potential source of exposure to Guam residents (Williams 1993).

During the site visit, ATSDR met with a community representative of Guam's indigenous Chamorro Nation community group. According to the representative, no community members expressed specific health concerns they attributed to Andersen AFB. Most health concerns were general concerns over what impact waste disposal may have on public health (Williams 1993). These concerns appeared to be intensified by the possibility of the Air Force returning portions of Andersen AFB's excess land containing waste sites to the public domain (USAF 1993).

Follow-up site visits were conducted in January 1999 and May 2000 to meet with Air Force and local regulatory agency representatives, collect additional data, observe the status of remedial activities, confirm previously identified pathways of exposure and define any new exposure pathways to chemical contamination released from Andersen AFB.

Demographics

The most recent population figures available, taken from the 1995 Island census, indicate that Guam's population is just over 140,000 people (DOI 2001). Census data for the island however, has been criticized for possibly not counting transients, squatters, and other hard-to-reach individuals; therefore, some estimate the island's population be even greater (USAF 1993). Over three-fourths of the island's inhabitants live in close proximity to Andersen AFB in Guam's northern or central regions. Three northern communities (Yigo, Dededo, and Tamuning) bordering Andersen AFB properties contain 47% of Guam's population. The two closest cities to Andersen AFB, Yigo and Dededo, total about 51,500 people (about one-third of the island's population) (USAF 1997). These cities are located less than 1 mile from military property and their water supplies are downgradient of known contamination plumes underlying Andersen AFB. Scattered, low-density populations reside in the small parcels of land dividing Yigo and Dededo from Andersen AFB property.

The community at Andersen AFB is largely self-sufficient, as most necessary services are provided on base. The population on Andersen AFB consists of approximately 508 military personnel living in dormitories, 1,278 military personnel living in base housing, and 2,849 military dependents living in base housing (Bias 1998). It is estimated that about three-quarters of the dependents are children. Approximately 300 Guam National Guardsmen and reservists use Andersen AFB for monthly training (USAF 2000).

Upi Elementary School abuts Andersen AFB's perimeter fencing on Route 15 in the vicinity of the back gate. Until 1997, the children of DOD employees attended the school. In 1997, elementary and middle schools were opened on Andersen AFB for children of Andersen AFB personnel, as well as for children of Navy, Air National Guard, and, to a more limited extent, Army personnel. There are about 799 students in pre-kindergarten through fifth grade at the elementary school and 338 students in grades 6 through 8 enrolled at the middle school (Andersen 2001). A high school located on base is attended by roughly 1,000 students (Bias 1998).

Land Use and Natural Resources

Land use at Andersen AFB is mixed: about 50% of the land is open space; 35% supports base operations (including a 1,750-acre airfield, aircraft maintenance and industrial areas, and base housing); and the remaining 15% supports community, recreation, and administrative functions

(Andersen AFB 1999a). Portions of the open space are restricted for operational or environmental reasons, such as explosive safety arcs and accident potential zones, cliff lines, and environmentally protected areas. Developed areas used for housing, administrative uses, and outdoor recreation are primarily located in the southern portion of the base. Housing areas are located away from most industrial use and aircraft areas (Andersen AFB 1999a).

ATSDR, in considering future land use, assumes that the mission to support Andersen AFB will stay the same. Any changes at Andersen AFB will likely serve to increase the functional efficiency of base operations. Certain Andersen AFB-controlled land will be returned to the government of Guam for public use. The Guam Land Use Plan of 1977 recommended the release of DOD-controlled property and recent legislation (Public Law 103-339) calls for the transfer of the Andersen AFB property, including Harmon Annex, Andersen Administrative Annex, and Andersen Radio Beacon, to the government of Guam (Andersen AFB 1999a). Other land along the northern tip of Andersen AFB's Northwest Field will be transferred to the U.S. Fish and Wildlife Service.

Air Force and Naval operations dominate land use activities in the northern areas of Guam, with each military branch on its respective installation. A main road loops around Andersen AFB properties and through the central portion of northern Guam. Access to this road is unrestricted; private, non-military residences line the roadsides. Along this road and scattered parcels of private land throughout northern Guam, limited home agriculture provides residents with a variety of garden produce. Some produce is also grown on Andersen AFB properties and eaten by local residents (EA Engineering 1995; USAF 1993).

Andersen AFB coordinates with local interest groups (e.g., the Marianas Audubon Society) to allow hiking and camping trips in limited, on-base areas. These trips do not involve visits to areas of known contamination (USAF 1999). Most trails are located in jungle areas near the perimeter of the base. Camping facilities are located on Tarague Beach, an area with no known contamination. All on-base hiking and camping trips are carefully monitored by the Air Force's Conservation Officer (CEVR). CEVR maintains a list of hiking trails and trail users, all of whom must obtain clearance passes from the Air Force to pass through military property. Additionally, two wildlife protection and natural preservation reserves are located in northern Guam adjacent to Andersen AFB property. Operations occurring at Andersen AFB do not appear to affect these conservation areas (EA Engineering 1995).

Approximately eight extended families own property along a stretch of Urunao Beach, which is just northwest of Northwest Field (USAF 1993). These landowners must pass through Andersen AFB to access their property. No one appears to live there full time, but some of the family members use the land for farming or recreation. The beach line where the families might swim is far from the cliff sites, so it is unlikely that people swimming at the beach will come in contact with material at the Northwest Field.[(1)]

Andersen AFB is situated on a limestone plateau, bounded on the north, east, and west by steep cliffs rising 500 feet above sea level. The plateau is composed of thick coralline limestone bedrock, which contains a freshwater lens aquifer. The limestone bedrock is very porous and permeable. No streams or natural drainage features exist on the plateau, because rainfall infiltrates the limestone bedrock extremely rapidly (USAF 1996; SAIC 1991).

The Northern Guam Lens Aquifer is used as a drinking water source. Under the Safe Drinking Water Act, the aquifer has been designated a sole source aquifer. This designation is based upon two criteria: (1) the aquifer supplies drinking water to 50% or more of an area's population and (2) if contaminated, the aquifer would present a significant risk to health. The aquifer is also protected under the GPZ. The aquifer is divided into six subbasins (Yigo, Andersen, Agafo Gumas, Finegayan, Mangilao, and Agana) based on natural, subsurface watershed divides (Barret et al. 1982). Each subbasin contributes drinking water to the Northern Guam Lens Aquifer, with the Yigo Subbasin contributing the most significant portion of aquifer recharge. The other subbasins are essentially undeveloped.

Quality Assurance and Quality Control

In preparing this public health assessment, ATSDR has reviewed and evaluated information provided in the referenced documents. Documents prepared for CERCLA and Resource Conservation and Recovery Act (RCRA) programs must meet certain standards: specified quality assurance and control measures must be taken for chain-of-custody procedures, laboratory procedures, and data reporting. The validity of the analyses and conclusions drawn in this document depends on the availability and reliability of the referenced information. The environmental data presented in this PHA come from site characterization, remedial investigation, and groundwater monitoring reports prepared by the Air Force under CERCLA and RCRA. Based on our evaluation, ATSDR has determined that the quality of environmental data available in site-related documents is adequate to make public health decisions.

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1. The Urunao Dump sites, which lie just on the edge of the Northwest Field OU, are being proposed as IRP 40 (USAF 2000). ATSDR does not know at this time whether or to what extent investigations associated with this area will extend to privately held land.

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EVALUATION OF ENVIRONMENTAL CONTAMINATION AND EXPOSURE PATHWAYS

Introduction

What is meant by exposure?

ATSDR's PHAs are exposure, or contact, driven. Given sufficient exposure levels, chemical contaminants disposed of or released into the environment have the potential to cause adverse health effects. However, *a release does not always result in exposure*. People can only be exposed to a contaminant if they come in contact with that contaminant. Thus, people can be exposed if they breathe, eat, or drink a substance containing the contaminant or if their skin touches a substance containing the contaminant.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site conditions to determine if people could have been, are being, or could be exposed to site-related contaminants: scenarios are evaluated for past, current, and future exposure. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation.

ATSDR then identifies an exposure pathway as completed or potential, or not completed. If a pathway is not complete, there can be no exposure and ATSDR eliminates that pathway from further evaluation. A completed exposure pathway exists in the past, present, or future if all elements of human exposure link the contaminant source to a receptor population. A potential pathway is one that ATSDR cannot rule out, as conditions may change that could result in a future completed pathway.

If exposure was, is, or could become possible, ATSDR scientists consider whether contamination is present at levels that might affect public health. ATSDR scientists select contaminants for further evaluation by comparing them against health-based comparison values (CVs). CVs are developed by from scientific literature available on exposure and health effects. These CVs are derived for each of the different media. CVs reflect an estimated contaminant concentration that is *not likely* to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., amount of water or soil consumed or amount of air breathed) and body weight.

CVs are not thresholds for adverse health effects. CVs establish contaminant concentrations many times lower than levels at which no effects were observed in experimental animals or human epidemiologic studies. If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (for example, duration and frequency), the toxicology of the contaminant, other epidemiologic studies, and the weight of evidence to assess the possibility of health effects.

Some of the CVs used by ATSDR scientists include ATSDR's environmental media evaluation guides (EMEG), reference dose media guides (RMEG), and cancer risk evaluation guides (CREG), and also EPA's maximum contaminant levels (MCL). MCLs are enforceable drinking water regulations developed to protect public health. CREGs, EMEGs, and RMEGs are non-enforceable, health-based CVs developed by ATSDR for screening environmental contamination for further evaluation.

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 1-888-42ATSDR (1-888-422-8737).

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual from contact with a contaminant depend on the exposure concentration (how much), the frequency and/or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (the combination of contaminants involved). 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 as a result of exposure to a contaminant in the environment.

In a situation involving environmental contamination, there is usually considerable uncertainty about the true level of exposure to that contamination. To account for the uncertainty and to be protective of public health, ATSDR scientists typically use high-end, 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 exposure, taking into account scientific information from the toxicologic and epidemiologic literature about the health effects from exposure to hazardous substances. Figure 3 provides an overview of ATSDR's exposure evaluation process.

What exposure situations were evaluated for Andersen AFB?

ATSDR identified five exposure situations at Andersen AFB for further evaluation: consumption of contaminated groundwater, consumption of local biota, contact with contaminated surface soil, exposure to radon in on-base buildings, and encounters with physical hazards. Our evaluation is summarized in Appendix A, Table 1, and discussed in greater detail in the following discussion. To acquaint the reader with terminology and methods used in this PHA, Appendix B provides a glossary of environmental and health terms presented in the discussion and Appendix C describes the methods ATSDR used to estimate exposure.

It should be noted that ATSDR analyzed all 39 of Andersen AFB's IRP sites to determine if they are associated with past, current, or future public health hazards. Appendix A provides a description and a summary of our evaluation for each site. Our review indicated that most sites at Andersen AFB are not associated with any known public health hazards because: (1) no site-related contaminants are present, (2) contaminant concentrations detected are too low to pose a health hazard, or (3) past and current exposure to the general public has been prevented.

ATSDR examined potential air contamination and found that the ambient air of Guam remains relatively clean at all times due to prevailing winds that carry clean air from the ocean across the island (USAF 1998a).

Evaluation of Groundwater Exposure Pathway

Conclusions

After detailed review of the available data, ATSDR concludes that no apparent public health hazards are associated with the use (past, current, and future) of groundwater from municipal, military, or private production wells.

Discussion

Andersen AFB's Hydrogeology

Andersen AFB property overlies five of the six groundwater subbasins of the Northern Guam Lens Aquifer: Yigo, Andersen, Agafo Gumas, Finegayan, and Mangilao (see Figure 2).[(2)] Three subbasins, the Andersen, Agafo Gumas, and Finegayan, underlie the main base property. Part of the Yigo subbasin lies under the MARBO Annex. The Yigo Subbasin groundwater flows west-southwest, toward Tumon Bay; Andersen Subbasin flows east and northeast; Agafo Gumas Subbasin flow patterns are unpredictable; and Finegayan Subbasin flows northward (EA Engineering 1998). The subbasins are presumably separated from one another by buried volcanic formations that create subsurface watershed divides (SAIC 1991). Past IRP investigations and documents have assumed that this volcanic material prevents groundwater contaminants from passing between the subbasins, but studies to date do not confirm these hydrogeological boundaries (ICF 1994).

Groundwater Use

The Northern Guam Lens Aquifer serves as a source of potable water for Andersen AFB and residents of Guam. Currently, the aquifer supplies approximately 70% of the drinking water to Guam and surface water provides the remaining 30% (SAIC 1991).[(3)] All of Andersen AFB water comes from the Yigo Subbasin, while about 47% of Guam's water comes from the Yigo, Andersen, Agafo Gumas, and Finegayan Subbasins (USAF 1998b).

Andersen AFB supports nine production water wells that have the ability to draw groundwater from the Yigo Subbasin of the Northern Guam Lens Aquifer for military potable water/drinking water uses. The production wells are: military well (MW) 1, 2, 3, 5, 6, 7, 8, and 9 in the MARBO Annex and one well (the Tumon-Maui well) located at Tumon Bay (Andersen AFB 1999a). Since the mid-1990s, both MW-2 and the Tumon-Maui wells have been off line because of environmental contamination concerns. The operating production wells provide approximately 2.5 to 3.2 million gallons of water a day for the base. When it was operating, the Tumon-Maui well supplied the bulk of the water, providing over 30% of the base's water capacity (Earth Tech 1998). Through the GEPA's groundwater protection program, the Air Force maintains a 1,000-foot protective zone around the water supply wells. The Andersen Subbasin reportedly supplied groundwater to the base during the 1940s and 1950s, but those wells are no longer used for drinking water due to poor water production and/or high salinity (SAIC 1991).

Since the 1950s, Andersen AFB has operated a water distribution system. Water drawn from each production well enters the base's looped distribution system, where it is blended with water from other wells before being distributed to Booster Stations 2 and 3 for chlorination (SAIC 1991; Andersen AFB 1999a). Groundwater from MW-1 and MW-3 are generally treated at Booster Station 2 (as were MW-2 and the Tumon-Maui when they were on line). Occasionally, all water is treated at Booster Station 3. (Two air stripping towers have also been added to Booster Station 2 to remove volatile organic

compounds, or VOCs, from water originating from MW-2 and the Tumon-Maui well.) The water is then stored at one of three larger or several smaller water storage tanks, including Tank No. 2, located at Booster Station 2, Tank No. 4, located at Booster Station 3, and the Santa Rosa Reservoir. The Santa Rosa Reservoir (the largest tank, with a capacity of 2 million gallons) provides pressure for the distribution system. Andersen AFB's water supply distribution lines are prone to corrosion, and many of the valves are old and rusted (Earth Tech 1998). Since 1993, the Air Force has been systematically replacing the corroded distribution lines within the family housing area. They will continue to upgrade the system through 2001 (Andersen AFB 1999a).

The Northern Guam Lens Aquifer also yields approximately 22 million gallons of water per day via 85 production wells owned and operated by the Public Utility Agency of Guam (GWA). Twenty of these GWA production wells are located near Andersen AFB property and have been evaluated as if they are potentially at risk for contamination associated with Andersen AFB.

There are seven other active production wells, not owned by the Air Force or GWA, that are on or adjacent to Andersen AFB property. Two of these wells water a golf course near the Northwest Field OU (Andersen Subbasin water); two are hand-dug wells on private property north of the Northwest Field (Agafo Gumas Subbasin water); two (one of which is blocked) are United States Navy wells in the Harmon Annex OU (Finegayan and Yigo Subbasin water); and one is a United States Geological Survey well in the Main Base OU (Andersen Subbasin water). The two private production wells are the only wells used for drinking water (EA Engineering 1998). Each private well serves one extended family and neither well is used on a full-time basis.

Groundwater and Drinking Water Quality

On-Base Groundwater Monitoring Wells

Andersen AFB began monitoring groundwater in 1987 to characterize the distribution and concentrations of contaminants in groundwater associated with the base and its annexes: the Main Base, the Northwest Field, the MARBO Annex, and the Harmon Annex. (The Air Force has stopped monitoring wells at the Harmon Annex because of lack of evidence of groundwater contamination [Dames & Moore 2000]). They collected samples routinely from a series of *groundwater monitoring wells* and analyzed the samples for VOCs, metals, and other site-related compounds. Samples from groundwater monitoring wells indicate the extent of the contamination and whether any contaminants are moving toward drinking water supplies. Figures 4a and 4b illustrate site locations, and Figures 5a and 5b show suspected groundwater plumes.

VOCs and metals have been detected in the groundwater monitoring wells that draw from the Yigo, Andersen, and Finegayan Subbasins. Groundwater contaminant

concentrations that exceeded ATSDR's CVs and EPA's maximum contaminant levels (MCLs) are TCE, PCE, carbon tetrachloride, and lead. High levels of TCE have appeared in a cluster of monitoring wells on the northwest side of the MARBO Annex (Yigo Subbasin), near the Waste Transfer Stations. The highest levels of TCE (up to 466 parts per billion, or ppb, in October 1999) have been consistently found in the deep monitoring well IRP 31, located at IRP 37/War Dog Borrow Pit directly south of the CPA Power Plant (Dames & Moore 2000). Additionally, elevated levels of PCE have been measured in monitoring wells IRP 14 (up to 26 ppb in 1989) and IRP 29 (14 ppb in 1997) adjacent to the MARBO Annex laundry. The dry cleaning facility at the laundry may, in the past, have discharged PCE to the base sanitary sewer via floor drains (Montgomery Watson 1998). PCE levels detected at well IRP 14 have steadily declined over the years, but, as of 1999, were still above EPA's MCL of 5 ppb (Dames & Moore 2000).[(4)]

Investigations revealed that, in the groundwater beneath the Northwest Field OU and the Harmon Annex OU, VOCs and metals were not present or existed only at low levels. Contamination was found at the Main Base monitoring wells IRP 3 and USGS-150: at those wells, VOCs (TCE, PCE, or carbon tetrachloride) and metals (lead, chromium, and cadmium) exceeded EPA's MCL (EA Engineering 1998). No base drinking water wells, however, exist near these affected monitoring wells.

On-Base Production Wells (Drinking Water Supply Wells)

The Air Force collects samples from *on-base production wells.* These wells supply Andersen AFB with its source of drinking water. The Air Force routinely monitors these wells under requirements set forth by EPA's the Safe Drinking Water Act to ensure safe drinking water for base workers and residents. Currently, drinking water quality data are collected on a biannual basis. Production wells in the MARBO Annex and in the Tumon-Maui have also been extensively monitored since 1978 for select compounds, including TCE, methylene chloride, pesticides (e.g., endrin, lindane methoxychlor, toxaphene, 2,4,5,-T, 2,4-D), nitrates, and certain metals (SAIC 1991).

Through their routine monitoring, the Air Force discovered TCE in samples collected from base water supply wells MW-1 and MW-2 at levels above EPA's MCL (5 ppb). Both these wells are west of, and slightly downgradient from, monitoring well IRP 31, where monitoring found elevated levels of TCE. The TCE concentrations in MW-1 and MW-2 have fluctuated over time. For example, TCE in MW-1 increased from 2 ppb in 1978 to about 8.5 ppb in 1988, and then decreased to about 0.8 ppb in 1999. Even higher levels of TCE have been detected in MW-2, where concentrations fluctuated from a high of about 39 ppb in 1978 to less than 5 ppb in 1985, increased to about 24 ppb in 1986, and then decreased to 2.6 ppb in 1999 (Montgomery Watson 1998; Dames & Moore 2000). The Air Force closed MW-2 in October 1995 (USAF 2001).

Monitoring also found elevated levels of PCE in the Tumon-Maui well located in lower Tumon Village on Route 14. The Air Force shut down the well in 1995 after the concentrations of PCE collected that year averaged 10 ppb--levels that exceed ATSDR's CV and EPA's MCL of 5 ppb (Andersen AFB 1997). Booster Station No. 2, which received water from the well, contained an average of 6 ppb PCE.

Certain on-site production wells tested during the IRP investigations had elevated concentrations of metals (SAIC 1991). Antimony was detected above ATSDR's CV in two military production wells

(MW-2 at 0.4 parts per million, or ppm; MW-9 at 0.5 ppm). Elevated concentrations of beryllium occurred in MW-9, with a maximum detected concentration of 66 ppm. Although all these wells lie in or near the MARBO Annex OU and draw water from the Yigo Subbasin, the elevated metal concentrations do not appear to result from activities associated with Andersen AFB operations (EA Engineering 1998).

To address the contamination in the base production wells, the Air Force installed two air stripping towers at Booster Station 2. The air stripping towers were designed to remove up to 99% of the PCE and TCE before the drinking water reached the base taps. The towers have treated incoming water from MW-2 for TCE and water from the Tumon-Maui well for PCE. MW-2 and the Tumon-Maui well, however, closed again in 1999 due to calcification of pumps associated with air stripping towers. (The base planned to add sodium metaphosphate to the water supply to remedy the calcification and to resume operation.) Today, both MW-2 and the Tumon-Maui well are closed indefinitely. The base has no plans to reuse the Tumon-Maui well in the future (Earth Tech 1998; USAF 2001).

Except for the MW-1 and MW-2 wells (in the MARBO Annex) and the Tumon-Maui well, no other drinking water wells have been or are likely impacted by VOC contamination because either: (1) contamination is not present upgradient of the well or (2) contamination though present upgradient of the active well, is at relatively low levels.

Off-Base Drinking Water Supply Wells

ATSDR identified only one OU--the MARBO Annex OU, overlying the Yigo Subbasin--that has the potential to impact municipal drinking water wells. Specifically, in the eastern Yigo Subbasin, a TCE plume appears to originate in the vicinity of two waste piles, IRP 23/WP-5 and IRP 20/WP-7 (SAIC 1991). TCE contamination, however, has not been detected in active, downgradient municipal wells. Another Yigo Subbasin plume, containing PCE at a maximum detected concentration of 26 ppb, appear to originate from unknown sources near the former MARBO Laundry Facility and WP-6 in the MARBO Annex (SAIC 1991). No PCE contamination has ever been detected in the water of the northern city of Dededo.

The two private wells north of the Northwest Field are still in used as a source of drinking water Groundwater monitoring results for the Northwest Field revealed that VOCs and metals were either not present or existed only at low levels, and that contamination did not appear to be moving in a plume north toward the private wells (EA Engineering 1998).

Evaluation of Public Health Hazards

Past Exposure

TCE and PCE are the only contaminants that were detected in active on-base drinking water wells above ATSDR CVs and EPA's MCL. Historically, TCE was consistently detected at the wellhead in two (of the nine) drinking water wells located in the MARBO Annex. These wells supplied Andersen AFB with potable water (SAIC 1991; Montgomery Watson 1998). Elevated PCE levels were detected in the Tumon-Maui well (Earth Tech 1998; Montgomery Watson 1998). The maximum detected TCE concentrations at MW-1 and MW-2 were 8.5 and 39 ppb, respectively (SAIC 1991; Montgomery

Watson 1998). The maximum concentration of PCE at the Tumon-Maui well was 10 ppb. PCE concentrations in the distribution system were less than at the wellhead, but they still slightly exceeded ATSDR's CV and EPA's MCL of 5 ppb (Williams 1993; Andersen AFB 1997).

ATSDR did not identify any completed groundwater exposure pathways in the Main Base OU, Northwest Field OU, or Harmon Annex OU, because no drinking water wells are located in these areas. Exposure, if any, could only come from drinking water supplied by wells in the MARBO Annex or the Tumon-Maui well.

To evaluate whether harmful exposures occurred, ATSDR conservatively estimated past exposure doses to TCE- and PCE-contaminated groundwater (see Appendix C) and found that its dose estimates were below levels of public health concern, even when assuming that an individual drank all his/her water from the affected wells for over a 30 year period. Therefore, ATSDR concludes that *no apparent public health hazards* are associated with the past ingestion of groundwater from Andersen drinking supply wells. The Air Force further minimized past public exposures to contaminated groundwater by installing air strippers to treat water from MW-2 and the Tumon-Maui well.

As discussed above, ATSDR also evaluated all municipal drinking water wells near Andersen AFB. Only contamination in the MARBO Annex OU (specifically, two plumes in the Yigo Subbasin) has the potential to impact municipal drinking water wells. This contamination, however, has not been detected in active, downgradient municipal wells or in the water of the northern city of Dededo. Therefore, the public has never been exposed to VOC-contaminated drinking water via GWA wells.

ATSDR concludes that *no public health hazards* are associated with past exposures via municipal drinking water wells.

Current Exposure

Today, the affected wells, MW-2 and the Tumon-Maui well, are closed. In Andersen AFB's other production wells and in the distribution system, no contamination is being detected at or above ATSDR CVs or EPA's MCLs (Williams 1993). Therefore, drinking water from the military wells is not expected to pose a public health hazard. In addition no off-base GWA production wells or nearby private wells have contained TCE or PCE concentrations above ATSDR CVs for drinking water. VOC concentrations in the Yigo Subbasin have not increased and area drinking water meets federal standards. Therefore, ATSDR concludes that *no public health hazards* are currently associated with the ingestion of Andersen AFB, municipal drinking water, and private well water.

Future Exposure

The Air Force has installed air striping units that will remove VOCs from MW-2 and the Tumon-Maui water if and when the wells are restored to service (Earth Tech 1998). These activities, combined with other remedial and interim activities (see Appendix A), have eliminated potential future exposure pathways and potential sources of groundwater contamination. Furthermore, on-base drinking water quality will continue to be closely monitored and land use restrictions will regulate the installation of new wells in the annex (Montgomery Watson 1998). Therefore, ATSDR concludes that future

exposures to drinking water from the Andersen AFB distribution system pose *no public health hazards*.

Off-base municipal wells potentially at risk for future contamination from Andersen AFB will continue to be monitored biannually. ATSDR found no indications that contamination levels will increase in the future. Furthermore, ATSDR was unable to locate any plans to construct new production wells within plume boundaries or in areas downgradient of plumes. It is highly unlikely that future wells will be situated in areas of known groundwater contamination. If wells were to be built, regulatory agencies would require cleanup of the groundwater to conditions that are acceptable for drinking. Therefore, ATSDR concludes that future exposures to GWA production well water pose *no public health hazards*.

Evaluation of Biota Exposure Pathway (Food Chain)

Conclusion

ATSDR concludes that no apparent public health hazards are associated with the consumption of locally grown produce or deer from Andersen AFB.

Discussion

Terrestrial Biota Use at Andersen AFB

People regularly consume papaya and other edible fruits grown on and off base, but access to on-base produce is limited. Some Guam residents recreationally hunt Sambar deer, wild pigs, and monitor lizards in areas around Andersen AFB (EA Engineering 1995; USAF 1993). Some hunters with permits may also hunt at Andersen AFB. People eat deer muscle, pig muscle, and pig skin tissues, but no reports indicate that people eat animal liver (the liver is generally the most highly contaminated tissue in an organism). No Guam residents surveyed during IRP investigations claimed to eat monitor lizard, but some individuals reportedly knew people who had eaten lizard muscle (EA Engineering 1995).

The only other edible macro-species present in Guam's northern limestone forest are the brown tree snake, Marianas Fruit bat, and the Philippine turtle-dove. Local residents do not eat brown tree snakes. ATSDR does not consider the consumption of bat and dove tissue to be likely human exposure pathways. ATSDR did not evaluate this consumption further, due to the limited numbers of these two species and the bat's protected endangered-species status (EA Engineering 1995; USAF 1993).

Terrestrial Biota Contamination and Potential Exposures

During the IRP, field investigators collected and sampled Sambar deer, wild pigs, monitor lizards, brown tree snakes, and papaya from areas on and off base (see Figure 6). Thirty-six chemicals (metals, pesticides, and semi-volatile organic compounds [SVOCs]) were detected in these samples. ATSDR evaluated these chemicals to determine if there are potential exposure pathways associated with the biotic transport of contaminants originating from Andersen AFB. Two contaminants, arsenic and aluminum, exceeded CVs (see Appendix D), and ATSDR estimated exposure doses and evaluated

potential health hazards associated with these contaminants. Using highly conservative assumptions, ATSDR estimated human exposure doses from the consumption of local biota. Our estimated doses were below doses associated with adverse human health effects. Uncertainties surrounding evidence for arsenic and aluminum toxicity at such low-level environmental exposures strengthen ATSDR's conclusion that there are *no apparent health hazards* (past, current, or future) associated with consumption of local biota.

Evaluation of Soil Exposure Pathway

Conclusion

ATSDR concludes that no public health hazards are associated with public exposure to contaminated soil at Andersen AFB.

Discussion

Military practices at various locations across Andersen AFB have resulted in spills or releases of chemicals to the surrounding ground surface (see Appendix A for site-specific data). The Air Force conducted environmental investigations to characterize the type and extent of contamination in the surface and subsurface soil at each site. ATSDR has used the Air Force's surface soil concentrations in this public health evaluation: the public is most likely to come in contact with the uppermost, or surface, layer of soil. (Please see Appendix A for the status of soil remediation action at each IRP site.) The type and extent of soil contamination are discussed below (by OU) and further summarized in Appendix A of this document.

Soil Monitoring Data

Main Base OU: The Main Base served as the Air Force's B-29 facility on Guam during World War II, as an ammunition storage area during the Korean War, and as a base for B-52 bombers and stratotankers during the Vietnam Conflict (USAF 2000). In support of these activities, the Air Force used landfills, cleaning operations, underground storage tanks (USTs), and fire training areas. Operations and waste handling practices at these locations released contaminants into the surrounding soil. Site investigations have revealed metals, SVOCs, polychlorinated biphenyls (PCBs), and pesticides in soil at many of the 23 IRPs located at the Main Base OU.

Some of the highest concentrations of metals were detected at the landfills, where lead was detected relatively frequently and at relatively high concentrations. For example, lead was detected at IRP 2/LF-2 (up to 8,300 ppm), IRP 5/LF-7 (up to 57,000 ppm), and IRP 10/LF-14 (up to 40,000 ppm)--at levels above EPA's soil screening value for children of 400 ppm. Other metals found in elevated concentrations include arsenic, chromium, and cadmium. IRP 2/LF-2 and IRP 5/LF-7 were used for sanitary trash disposal, while IRP 10/LF-14 stored construction debris (USAF 2000). Many of the areas are being further investigated to determine whether remediation will be required.

Northwest Field OU: The Northwest Field encompasses 4,387 acres on the northwest coast of Guam. During World War II, airfields on the land supported fighter planes and bombers. Since that time, the Air Force has deactivated the airfields and used the property for temporary housing, as a satellite

control facility, and as a radar bombing scoring facility. The spills and releases caused by operations that supported the runways (including fuel storage, cleaning, and maintenance) are matters of potential environmental significance. The OU located in this area encompasses seven IRP sites, including four landfills (IRP 7/LF-9, IRP 16/LF-21, IRP 17/LF-22, and IRP 21/LF-26) that contain runway construction debris, a waste pile (IRP 30/WP-4), a chemical storage area (IRP 31/CS-4), and a dump site (Ritidian Point). Also, the Urunao Dump sites are being proposed for investigation under this OU.

Monitoring revealed relatively high levels of metals in soil at IRP 16/LF-21, where past disposal of sanitary trash resulted in lead concentrations up to 27,000 ppm and chromium concentrations up to 6,500 ppm. Lead and chromium were also measured in soil at IRP 31/CS-4 at concentrations up to 3,100 ppm and 1,300 ppm, respectively. Lower concentrations have been measured at the other investigated landfills (IRP 17/LF-22 and IRP 21/LF-26) in this OU. The Air Force plans to remove contaminated soil from IRP 16/LF-21 and IRP 31/CS-4, and they have recommended no further action for IRP 7/LF- 9, IRP 21/LF-26, IRP 17/LF-22, and IRP 30/WP-4. Environmental investigations are still underway at the Ritidian Point dump site.

MARBO Annex OU: The MARBO Annex covers across 2,431 acres and has been used for administrative functions and base housing. The six IRP sites at the MARBO Annex OU include IRP 23/WP-5, IRP 22/WP-6, IRP 20/WP-7, IRP 24/LF-29, IRP 37/War Dog Borrow Pit, and IRP 38/MARBO Laundry. Metals and SVOCs have been detected in soil at the waste piles and IRP 24/LF-29. Again, lead was detected frequently and in high concentrations. Some of the highest lead concentrations in the OU were detected at IRP 20/WP-7 (18,000 ppm) and IRP 24/LF-29 (120,000 ppm) (USAF 2000). Remedial actions have been completed at the IRP 38/MARBO Laundry and IRP 20/WP-7, while remedial actions proposed in the MARBO Annex ROD have begun at IRP 24/LF-29 and IRP 22/WP-6.

Harmon OU: Harmon Annex sits on 1,817 acres and is the smallest area of the base. During World War II, Harmon Annex supported non-industrial functions, but industrial facilities were subsequently built on the land to support Korean War operations. Today, most of the buildings have been removed or abandoned. The area consists of three IRP sites: IRP 18/LF-23, IRP 19/LF-24, and IRP 39/Harmon Substation.

Soil sampling completed at the Harmon OU identified elevated levels of metals, including 13,000 ppm of lead at IRP 19/LF-24 and up to 940 ppm of lead at IRP 39/Harmon Substation. Much lower concentrations of metals and other contaminants were measured at IRP 18/LF-23. Contaminated soil was removed from IRP 19/LF-24 and IRP 39/Harmon Substation in July 1999. No cleanup of contaminated soil was warranted at IRP 18/LF-23 because further investigations indicated that the site may not have been used as a landfill (USAF 2000).

Evaluation of Public Health Hazards

Past and Current Exposures

Trespassers are potential receptors to Andersen AFB soil contamination.[(5)] They might come in contact with contaminants when handling soil or by inadvertently eating soil through hand-to-mouth

activity. Inhalation of soil particles is not considered to be a significant source of exposure because all land on IRP sites is either extensively vegetated, paved, or enclosed.

ATSDR assumes that any soil contact would be with surface layers, since trespassers would be unlikely to dig on site. Moreover, any exposure would be infrequent and of short duration, because military security measures prevent trespassers from accessing industrial areas and base facilities (places where IRP sites are located). Such minimal, infrequent exposure to on-site contaminants, if it occurs at all, would not be expected to result in adverse health impacts. In addition, most Andersen AFB sites display warning signs about site hazards which should prevent and/or reduce potential exposure to contaminated soil.

Future Exposure

Future land use and accessibility of certain IRP sites will remain restricted due to institutional controls and deed restrictions, even if the Air Force returns its excess lands to the people of Guam. Note that certain sites are being remediated by the Air Force as a precautionary measure to prevent exposure to on-site workers and to prevent contamination from leaching into groundwater. These remedial actions are conducted with oversight by EPA and the GEPA to ensure protection of human health and the environment and are detailed or will be detailed in the RODs prepared by the base. In evaluating available monitoring data and proposed remedial actions, ATSDR has identified no past, current, or future public health hazards associated with contaminated soil.

Evaluation of Radon Exposure Pathway

Conclusion

Naturally occurring radon gas has entered certain on-site military housing units at levels that exceed EPA's guidance level of 4 pCi/L. People who live in these units could have been exposed to radon. The full extent of these exposures is unknown; therefore, ATSDR is not certain what potential public health hazards are associated with the exposures. The Air Force has mitigated radon at most of the affected housing units and plans to continue their sampling and mitigation efforts.

Discussion

Radon Monitoring and Mitigation Programs

Radon naturally occurs at high levels on Guam; it does not originate from military activities at Andersen AFB. Radon levels on Guam will fluctuate, even in a given building structure, primarily because the island's daily tremors constantly open and close ground fissures through which radon escapes (Bias 1999). Since 1987, the Air Force has conducted several monitoring programs to characterize radon levels in indoor air of on-base buildings.

Table 3 summarizes the findings of Andersen AFB's radon monitoring programs. In their initial study conducted in 1987 and 1988, the Air Force tested radon levels in 33 housing units. Results from this testing indicated that indoor radon levels of 18 units exceeded EPA's recommended action level for radon of 4 pCi/L (14 houses contained 4-20 pCi/L of radon and 4 houses contained 20-200 pCi/L of radon) (Bias 1999). Based on these results, EPA and the Air Force designated Andersen AFB "high risk," meaning that all habitable structures required sampling.

Following that determination, the Air Force conducted several broader monitoring programs to characterize the extent of radon contamination in all occupied housing units and in other public buildings across the base. In 1988 and 1989, the Air Force placed 1,754 radon monitors in all on-site housing unit for 60 days. Of the 1,754, monitors 1,406 were analyzed, with results showing that 74 houses contained 20-200 pCi/L of radon and 1 house exceeded 200 pCi/L of radon. All houses with radon above 20 pCi/L were mitigated and re-sampled until all radon gas concentrations were below 4 pCi/L. For 617 houses with radon 4 and 20 pCi/L, the Air Force deployed one-year monitors to verify that radon levels remained below 20 pCi/L (Bias 1999).

The Air Force conducted another round of monitoring in late 1989, which showed that about 40% of the tested structures (835 houses, 14 apartments, the Chapel pre-school, and the youth center) contained radon levels between 4 and 20 pCi/L and another 4% (84 houses and one apartment) contained levels between 20 and 200 pCi/L. The remaining structures contained radon at levels below EPA's recommended action level. (Air Force records suggest that 216 of the one-year monitors may never have been retrieved or analyzed.) Mitigation of the housing units was directed toward installing over-sized air conditioner fans to give the houses slightly positive pressure.

During ATSDR's February 1993 site visit, ATSDR identified radon as a potential contaminant of concern. Six months later, the Air Force retested the air in 1,390 military family housing units for radon levels. Of those units tested, 785 units were below EPA's recommended action level of 4 pCi/L of radon and required no mitigation; 743 units were above 4 pCi/L and were mitigated by Air Force contractors; and 124 units were above 20 pCi/L and were mitigated by the Base Civil Engineering Squadron. At this time, all the buildings considered most at-risk for radon contamination have been tested and mitigated as required to meet EPA guidelines, referenced in the 1988 Indoor Radon Abatement Act. Additional information can be obtained online at http://www.epa.gov/iaq/radon/pubs/index.html and at http://www.epa.gov/iaq/radon/

The Air Force continued regular monitoring and mitigation of on-site structures into 1993 (Bias 1999). In August 1993, however, a large earthquake (measuring 8.2 on the Richter Scale) struck Guam and interfered with radon monitoring and mitigation efforts. Currently, a comprehensive database does not exist to link pre-earthquake sampling results and radon mitigation efforts with post-earthquake activities. Without a comprehensive data set, the Air Force cannot readily determine if all on-site structures have been recently monitored, mitigated, and re-monitored as necessary. A statistical analysis of pre- and post-earthquake radon levels, however, indicates that radon levels in certain houses increased an average of 2 pCi/L after the earthquake.

In Andersen AFB's most recent radon monitoring program, conducted in July 1998, the Air Force collected 72 samples from a set of structures (37 houses and 35 non-house buildings) that lacked verifiable pre- and/or post-earthquake sampling and mitigation records. (Some of the homes had been

previously renovated.) Of the 37 sampled houses, 26 houses contained less than 4 pCi/L of radon and 8 houses contained 4-20 pCi/L of radon (4.59 to 17.51 pCi/L). None of the homes contained radon at levels greater than 20 pCi/L. In 1999, the Air Force renovated three houses located on Okinawa Lane that contained elevated radon levels (between 4 and 17 pCi/L). It is assumed that the radon levels at these residences have since dropped, but the Air Force lacks confirmatory sampling data. Four of the five remaining affected houses were previously renovated (two houses in 1991, one house in 1995, and one house in 1997). The Air Force plans to reassess the radon levels and mitigation design at these houses.

Among the 35 buildings (non-housing units), 33 buildings contained radon at levels below 4 pCi/L. Only two buildings contained levels greater than 4 pCi/L: one facility building contained radon at 5.89 pCi/L and another contained radon at 43.57 pCi/L (Andersen AFB 1999b).

As of May 2000, 755 of the 1,390 housing units on base have been renovated (Andersen 2000).

Currently, the Air Force is evaluating its overall radon program to ensure that they have adequately evaluated the risk in each on-site structure. The Air Force plans to begin sampling of renovated homes in 2001 to test the adequacy of the mitigation efforts (Andersen AFB 2000a). ATSDR identified radon in indoor air as a past, current, and potential future completed exposure pathway for some on-base residents.

Evaluation of Public Health Hazards

ATSDR is unable to fully assess the potential health hazards associated with past radon exposure at Andersen AFB. The full extent of past radon exposure at Andersen AFB remains unknown due to limited historical sampling data and uncertainties about individual exposures. Additionally, ATSDR does not have a health-based comparison value for radon, and EPA has not identified a reference concentration. EPA's carcinogen assessment has been withdrawn (formerly thought to be a human carcinogen) pending review of additional information regarding the potential of radon to cause cancer in humans.

Toxicologic studies report that radon exposure causes no acute or subacute health effects. The primary health concern associated with residential radon exposure is lung cancer, although there is currently no clear evidence that radon exposure causes lung cancer. A recent report from the National Research Council estimates that approximately 1 in 7 of all lung cancer deaths can be attributed to radon exposure, independent of smoking status, though these estimates are uncertain (BEIR VI 1999).

Many factors influence the risk of lung cancer resulting from radon exposure. Among these are the radon level, the duration of exposure, the time since initiation of exposure, the age of an exposed individual, and the individual's smoking habits. The combined effects of cigarette smoking and radon exposure place current and former smokers at particularly high risk for lung cancer. Epidemiologic studies show that individuals working in certain industries susceptible to radon releases are at greatest risk, because they are often exposed to high levels of radon over an extended period of time. In one study, uranium miners exposed to radon levels of 50 to 150 pCi/L in air for about 10 years have shown an increased frequency of lung cancer (ATSDR 1990), though this study suffers from several

weaknesses including lack of control for exposures to other agents that could contribute to lung cancer, such as silica and smoking.

ATSDR cannot determine with certainty whether the radon levels posed a past public health hazard for residents of Andersen AFB housing, but certain factors would suggest that the typical individual has a reduced likelihood of developing harmful health effects. They include:

- ***Limited period of exposure.*** Most residents of military housing reside on base for a 2-3 year period. This time period is much shorter than the duration of exposure reported for occupational studies in which workers developed health effects. Furthermore, the Air Force mitigation efforts have reduced radon levels and the potential for harmful health effects at the houses at greatest risk.

- ***Exposure to low air radon levels.*** Most tested buildings at Andersen AFB had radon levels below 50 pCi/L, the level associated with adverse health effects in workers.

The Air Force has been mitigating on-base housing levels of radon since 1989 and it plans to continue its radon testing and mitigation of residential units in 2001, as well as to expand its base program to other, lower priority buildings. The Air Force's continued commitment to mitigating naturally occurring radon in the housing units should greatly reduce current and future public health hazards from radon exposure.

Evaluation of Physical Hazards

Conclusion

Unexploded ordnance (UXO) exists in the Northwest field at Andersen AFB. To date, there have been no accidents involving UXO. Due to the implementation of educational programs, access restrictions and ongoing monitoring efforts, harmful contact with UXO is remote and does not pose a public health hazard.

Asphalt debris and exposed tar is located in the asphalt recovery area in the landfill complex. Access is restricted to the landfill complex. Trained workers entering the recovery area will be required to conduct activities in accordance with OSHA health and safety requirements, minimizing risk of health hazards.

Unexploded Ordnance

Unexploded ordnance (UXO) has been disposed of at IRP 17/ LF-2 and IRP 30/ WP-4, at the Northwest Field. The Northwest Field is restricted to public access, but certain areas are open to hunters with permits. There have been no recorded incidents of injuries resulting from encounters with UXO at Andersen AFB since the Air Force began disposing UXO at the landfills in the 1950s. Live UXO is dangerous and should be avoided. **If UXO is discovered, do not touch or tamper with it. Contact the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198**

There is a long history of people safely using areas cleared of UXO (QuantiTech 1997, Wilcox 1997). A nationwide study conducted by the U.S. Army Corp of Engineers (USACE) found no cases where people have been hurt upon encountering UXO. They found, however, that accidents occurred in cases where a trespasser removed the UXO and tampered with the item, or in cases of active disturbances, such as a worker digging into a buried UXO.

An encounter with a UXO item could possibly occur in the Northwest Field disposal areas. The probability of a hazardous encounter has been reduced through the current educational program and access restrictions at Andersen.

A recreational user of the Northwest fields may encounter UXO. It is unlikely that a harmful outcome would occur during an incidental encounter. However, prudence suggests that improved education, access restrictions, clear delineation of restricted areas and implementation of a monitoring plan will further reduce the likelihood of a future health hazard.

Exposed Asphalt Debris

Asphalt-containing drums left over from the construction of the Andersen's AFB runways and roadways during the early 1940s have been disposed of at IRP 35/W-1. The site spans 7 acres of the Main Base OU, away from residential and recreational property. Most of the drums at the site have deteriorated, allowing about 170,000 gallons of asphalt to empty onto the surrounding ground surface over time (Andersen AFB 1998a).

Cleanup at the site began in November 1997. The Air Force has cleared heavy vegetation, removed about 3,800 cubic yards of asphalt debris (primarily nonrecoverable asphalt soil) and then stockpiled the asphalt debris in drums on the ground at the site. Four-foot high soil berms now surround the piles. Also asphalt has been drained from about 8,000 recovered drums into six trenches that were dug into the limestone bedrock at the site. The 8,000 empty drums that once contained asphaltic material are stockpiled in the metal debris stockpile located on the northwestern portion of IRP 35/WP-1 (Andersen AFB 1998). The Air Force processed the asphalt in the trenches in an asphalt recovery system and then collected the recovered asphalt in more than 3,800 55-gallon drums.[(6)]

The exposed asphalt debris still remains at IRP 35/WP-1 as the base is awaiting the results of an impending pilot field study intended to identify appropriate landfill handling procedures (Andersen AFB 1998). Trespassers could enter the area and contact the exposed debris or asphalt remaining in the trenches since the area lacks signs or barriers to restrict public access.

Asphalt in the drums is a mixture of aggregate, sand, filler, bitumen, and occasionally a number of other additives. Some occupational studies have noted a higher than average rate of skin damage, such as reddening, blistering, or peeling, among people who produce or apply asphaltic material (ATSDR 2000). ATSDR is not aware of any studies that suggest that incidental contact with asphalt debris causes health effects. Trespassers could conceivably contact the material but in all likelihood the exposure would be brief and infrequent because the base's security measures prevent trespassers from accessing industrial areas. In addition, this area is located far from residential and recreational property.No apparent public hazards have occurred in the past or are likely to occur now or in the future from trespasser exposure. Trained workers entering the recovery area will be required to

conduct activities in accordance with OSHA health and safety requirements, minimizing risk of health hazards. Institutional controls such as controlled access and more visible warning signs should be adequate to prevent access by uninformed or unauthorized visitors to the area where they might encounter the exposed asphalt or asphaltic debris.

COMMUNITY HEALTH CONCERNS

Andersen AFB has a community relations plan (CRP) that provides guidance for involving the community and other interested parties in the remediation decision making process and for distributing information to these parties (USAF 1998). As part of its community relations activities, Andersen AFB has formed a restoration advisory board (RAB). The RAB, which is represented largely by local community members, meets periodically to review site documents and comment on Andersen AFB remedial actions. Through the public health assessment process, ATSDR has gathered information about health concerns identified in the CRP or voiced by community members at RAB meetings. Following is a summary of the community health concerns that have come to ATSDR's attention.

Concern: *Why is ATSDR assessing the site after cleanup activities have begun at the site?*

ATSDR's involvement at Andersen AFB focuses on public health (i.e., the health impact on the community as a whole). In evaluating potential public health hazards, ATSDR reviewed available environmental data, both available pre-and post remediation data, as well as any proposed remedial actions. Our review of the available data shows that *people have not come in contact with, nor are they expected to contact, hazardous substances from Andersen AFB at levels posing potential public health hazards*. Therefore, based on the available data, regardless of the stage of investigation, contamination from Andersen AFB poses no public health hazard. ATSDR is an advisory agency, so if hazards were identified, the PHA would recommend appropriate actions, such as additional cleanup measures, to be undertaken by responsible parties.

Site characterization and remediation at NPL sites may continue for years after releases are suspected. Likewise, remediation may occur before or after ATSDR's involvement begins. Sometimes, additional data are generated after remediation and after a PHA has been released to the public. In such cases, the PHA is updated. Therefore, if new data are collected or additional information is compiled that suggest the public health may be adversely affected as a result of or despite proposed or completed cleanup action, ATSDR will modify or add to the document in a way to reflect the public health implications of the additional data and recommend actions to stop or reduce exposures in its public health action plan.

Concern: *Will land returned to the government of Guam be safe for public use, particularly land occupied by IRP 20/WP- 7?*

Land transferred to the government of Guam will be either required to be free of harmful levels of contaminants specific to its intended use or encumbered with deed restrictions that indicate how the land can be safely used in the future. As noted earlier, land occupied by IRP 20/WP-7 will be transferred in the future to the government of Guam for public use. Due to past site operations,

however, soil at this location has become contaminated with metals, PCBs, and pesticide waste. The risk to humans is primarily driven by elevated soil lead concentrations. Certain surface soil samples exceeded EPA's guidance level for lead in soil (400 ppm), while deeper soil samples (greater than 12 feet) showed much higher levels. Left exposed or if disturbed, the lead-contaminated soil could pose an unacceptable risk for people who might routinely come in contact with the contaminated soil in the future.

The Air Force has placed a soil cover over the area to reduce the potential exposure of future users to high levels of lead in soil. Deed restrictions accompanying the transfer of the land will ensure that the land will be used in such a way to maintain the integrity of the soil cover and to minimize soil disturbances. Examples of non-intrusive future land uses proposed for the area include the operation of a non-residential maintenance yard or several storage areas.

As a reminder, ATSDR's goal at Andersen AFB is to evaluate whether any past, current, or future exposures could result in public health hazards. It is important to note that even though soil beneath Waste Pile 7 contains lead, a public health hazard can exist only if people come in contact with harmful levels of contamination. By following the land use restrictions and respecting the soil cover, ATSDR concludes that people should not come in contact with lead-contaminated soil from Waste Pile 7. However, as a precautionary measure ATSDR highly recommends that the deed restrictions stipulate that the land not be used by or for children (a population very susceptible to lead poisoning) and that the Air Force ensures the integrity of the soil cover at Waste Pile 7 before transferring the land to the government of Guam.

ATSDR understands that certain individuals may wish to use the land in ways other than those specified in the Air Force's deed restrictions. If deed restrictions do change or if the soil cover is removed or disturbed at some point in the future, ATSDR recommends that this potential exposure pathway be reevaluated.

Concern: *Have toxic chemical warfare agents been used or stored at Andersen AFB, and, if so, do they still exist in areas accessible by the public?*

Chemical warfare materiel were used and stored at Andersen AFB, but no information has been found describing bulk use, storage, release, or disposal of ***toxic*** chemical weapon agents, such as mustard gas or nerve agents. In reviewing site history and talking with site representatives about Andersen AFB, ATSDR learned that toward the end of World War II, the land now occupied by Andersen AFB served as an important operations center for military action in the Pacific theater. In supporting wartime activity, chemical warfare materials were used or stored at Andersen AFB but were limited to material necessary for the supply and operations of smoke generators and flame throwers. These types of materials are not considered to be toxic. There are no indications that bulk toxic chemical warfare materiel was ever sent to Guam in the documentation reviewed. Rather, bulk toxic munitions were commonly stored on the west coast of the United States and in Hawaii during World War II, and then on Japan during the Korean War (Hart Crowser 2000).

In 1978, the Army undertook an investigation to locate and remove chemical agent identification sets (CAIS) from 15 military installations nationwide, including Guam. The kits would have been used to identify enemy chemical warfare agents. It is believed that the military staff ordered the kits for toxic

gas identification training exercises. The Army investigators found an unknown quantity of CAIS, known as K951:War Gas Identification Sets, Instructional M1, and then transported the sets by airplane from Guam to Rocky Mountain Arsenal. Intact glass vials within the CAIS sets were found to contain diluted amounts of mustard gas, CG, lewisite, and PS. No nerve agents were found in these kits.

In July 1999, 16 additional CAIS were found buried in a field on a privately-owned farm near the village of Mong Mong. A team of representatives from EPA, the Army, Air Force, and Coast Guard removed the World War II era canisters and transported them to a temporary storage facility at Andersen AFB before final transport to Johnson Atoll for disposal. The land was used toward the end of World War II for a Navy ammunition depot. It is believed that these canisters contained CAIS.

Based on preliminary information available, it is highly unlikely that people have been or could be exposed to chemical agents or other hazards from these canisters. *The canisters were found intact, suggesting that no release of chemicals to the environment occurred from the time the canisters were buried until they were removed.* Furthermore,all kits discovered have been removed, so current and future exposures from discovered kits have been prevented. The USACE will survey the property for remaining canisters using metal detectors and ground penetrating equipment. Additional cleanup may be necessary depending upon their findings.

The discovery of these canisters suggests that the burial of canisters might not be an isolated incident and that other canisters could be buried elsewhere on Guam. The military has procedures in place to properly handle buried containers should they be discovered in the future (during the course of environmental remediation, for example). As a reminder, the chemical agents in CAIS kits can be toxic and should be handled only by trained individuals. Community members discovering suspected CAIS kits or related materials should not remove or further disturb the area. Rather, discoveries of the CAIS kits in the northern portion of Guam should be reported to the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198 and discoveries in the southern portion of Guam should be reported to the Navy EOD at (671) 339-8156.

ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children may be more sensitive to exposures than adults in communities with contaminated water, soil, air, and food. Children are more likely to be exposed to soil or surface water contamination because they play outdoors and often bring food into contaminated areas. For example, children may come into contact with and ingest soil particles at higher rates than adults do; also, some children with a behavior trait known as "pica" (frequent hand-to-mouth behavior)

are more likely than others to ingest soil and other nonfood items. Children are shorter than adults, which means they can breathe dust, soil, and any vapors close to the ground. Also, they are smaller, resulting in higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. ATSDR is committed to evaluating their special interest at sites such as Andersen AFB, as part of the ATSDR Child Health Initiative.

It is estimated that there are about 2,100 children living on the base. Enrollment at the elementary and middle schools on the base is 1,137. Enrollment at the Guam Elementary/Middle School and Guam High School is 668 and 3785 students, respectively (Andersen AFB 2001).However, these children/students are not exposed to contamination because access to contaminated areas is restricted and blocked by fencing. Thus, no past, current, or future health hazard is posed to children attending school on or near the base.

Data on the effects of radon exposure in children are limited. Differences in lung structure and breathing rates in children result in higher estimated doses that may make children more susceptible to the effects of radon than adults (Samet et al. 1989). Children also have a longer latency period ahead of them in which to develop cancer. However, there are currently no conclusive data on whether children are at greater risk than adults from radon exposure. Child exposure to radon in Andersen AFB housing units appears limited (a maximum exposure of approximately one or two years) because the families of active-duty Air Force personnel frequently move. Air Force personnel are taking active measures to reduce radon levels in base housing. There does not appear to be a public health hazard from radon exposure to children living in base housing.

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2. ATSDR found no relevant information describing potential environmental impacts that Andersen AFB activities may exert on the Mangilao Subbasin. This document, therefore, does not further discuss that Mangilao Subbasin.
3. Fern Lake provides an additional source of water for Guam, primarily for use by the Navy (Earth Tech 1998).
4. Note that the IRP well number does not necessarily match the IRP unit in which it is located.
5. On-site workers are also potential receptors, but ATSDR assumes that Occupational Safety and Health Administration requirements adequately protect the health of workers when they are on the job. On-site workers at Andersen AFB are not, have not been, and will not be exposed to contaminated soils except as part of their normal work responsibilities and material handling. Therefore, this public health assessment focuses exclusively on trespassers' exposure to contaminated soils.
6. Although no soil was removed, the Air Force took 10 "confirmatory" soil samples from the area. The results indicated that SVOCs and PAHs concentrations were safely below standards for residential and industrial uses. Metals, including aluminum (up to 220,000 ppm), chromium (1,340 ppm), and manganese (3,370 ppm) were detected at levels above EPA Region's 9 residential or industrial soil standards of 100,000 ppm for aluminum, 450 ppm for chromium, and 3,100 ppm for manganese.

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PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM

CONCLUSIONS

On the basis of its evaluation of available environmental information, ATSDR concluded that exposures to contaminants in groundwater, surface soil, and local plants and animals harvested for consumption are below levels that would cause adverse health effects. Since exposure to low levels of contamination occurred in the past and may still be possible, ATSDR has categorized this site as **no apparent public health hazard**. Because of the Air Force's education efforts, access restrictions and monitoring programs at Andersen AFB, contact with UXO and the possibility of harm is remote. ATSDR has categorized exposure to this physical hazard as **no apparent public health hazard.** In evaluating past exposures to radon in on-base housing, ATSDR concluded that these exposures posed an **indeterminate health hazard** because of the lack of monitoring data prior to 1987 (definitions of categories are provided in the glossary in Appendix E). Conclusions regarding media- and site-specific exposures are as follows.

1. No apparent public health hazard exists from volatile organic compounds (associated with military operations and activities) detected in the past in three production wells that supply Andersen AFB with drinking water. ATSDR evaluated exposure to the detected concentrations and determined that no apparent public health hazard exists because low levels of contamination and short durations of exposure would not be sufficient to cause adverse health effects. Current and future exposure to all groundwater contaminants of concern (TCE, PCE, carbon tetrachloride, and lead) above levels of health concern is unlikely. Andersen AFB has implemented remedial actions to remove groundwater contamination and continues to closely monitor groundwater quality in its nine production wells serving the base water supply.

2. Consumption of drinking water from known off-base water supplies poses no public health hazards associated with Andersen AFB because testing has revealed that contamination has not impacted off-site municipal or private drinking water supply wells.

   The three Northern communities (Yigo, Dededo, and Tamuning) bordering Andersen AFB property contain approximately 47% of the islands population. Yigo and Dededo are located within a mile from military property and their water supplies are downgradient of known groundwater contamination plumes underlying Andersen AFB. A groundwater plume from an unknown source appears to be originating from an area near the MARBO Annex. Continued

monitoring of groundwater contamination by both the Air Force and Guam regulatory agencies is critical to ensure that the water resources that off-base communities rely upon is protected from contamination.

3. Due to the proximity of private and municipal wells serving communities in the vicinity of the base, Andersen AFB continues to monitor off base groundwater plumes to ensure that these wells do not become contaminated.

   No apparent public health hazard exists (past, current, or future) from the consumption of local biota collected on- or off-base at Andersen AFB.

4. Although surface soil at certain locations at Andersen AFB contained contaminants (primarily VOCs, SVOCs, total petroleum hydrocarbons, pesticides, and metals) above screening levels, there is no completed pathway of exposure since the contamination is located in restricted access areas, areas of heavy vegetation growth and frequently occurs in subsurface soils which limits the opportunity for contact. Successful cleanup or removal of contamination and deed restrictions will prevent harmful exposures on land that will be returned to the government of Guam for public use.

5. An encounter with a UXO item could possibly occur in the Northwest Field disposal areas. The probability of a hazardous encounter has been reduced through the current educational program and access restrictions at Andersen. No accidents involving UXO have been reported to date. Historical data suggest that the probability of an encounter resulting in detonation is limited to instances where the UXO is actively disturbed, such as being handled, tampered with or dug into during excavation.

   It is unlikely that a harmful outcome would occur during an incidental encounter. However, prudence suggests that education, access restrictions and implementation of a monitoring plan will further reduce the likelihood of a health hazard. Due to the implementation of educational programs, access restrictions and ongoing monitoring efforts, harmful contact with UXO is remote and does not pose a public health hazard.

6. In the past, naturally-occurring radon levels in the indoor air of on-base housing units were above EPA's recommended action level of 4 pCi/L. The full extent of this past exposure pathway is unknown and therefore the hazards associated with potential exposures are uncertain. The Air Force has renovated 755 homes for radon abatement (as of May 2000). Only a few housing units recently tested contained elevated levels (between 4 and 20 pCi/L) of radon. The Air Force continues its radon monitoring and abatement program, and is taking action to ensure that base housing meets health guidelines established for radon.

RECOMMENDATIONS

1. The Air Force and Guam regulatory agencies should continue frequent monitoring of groundwater contamination that has the potential to impact private and municipal water supplies in the vicinity of Andersen AFB. Responsible agencies should provide close oversight of new drinking water well installation and provide community access to information on water quality and procedures for getting private well water tested.

2. Deed restrictions should be implemented to avoid future contact with any remaining contaminated soils prior to land transfer. The Air Force should ensure the integrity of the soil cover prior to land transfer to the Guam government. If deed restrictions change or soil cover removed or disturbed in a way that may result in contact with contaminated soils, ATSDR recommends that this exposure pathway be reevaluated.

3. The Air Force should continue educational efforts on UXO awareness and injury prevention directed toward recreational users of the Northwest fields.

   Additional education activities should be directed toward on-base schools and community centers to enhance public awareness on UXO safety. The United States Department of Defense (DoD) has developed the UXO Safety Education Program to help prevent injury by educating communities about the dangers associated with UXO. DoD designed this program as a "toolkit" from which DoD organizations and the public could use individual "tools" to enhance or supplement their local UXO safety programs. The "toolkit" consists of ready-to-use educational products and materials for classroom, home or community group use. Access to the UXO Safety Education Program is available to DoD personnel on the Defense Environmental Network and Information Exchange (DENIX) web site at http://www.denix.osd.mil/

4. The Air Force should continue ongoing abatement efforts, and ensure that radon gas is within acceptable limits before allowing building occupancy. Information on radon health hazards should be made available to on-base residents.

5. ATSDR recommends that the U.S. Air Force take a leadership role in conducting a campaign to provide information and outreach to Guam residents on how to recognize UXO and CAIS and what to do if further CAIS units are discovered. Possible partners include the U.S. Navy, Guam EPA and Guam Department of Health. Discoveries of the CAIS kits in the northern portion of Guam should be reported to the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198 and discoveries in the southern portion of Guam should be reported to the Navy EOD at (671) 339-8156.

6. ATSDR recommends future remedial investigations include collection and analysis of coconut crab, *birgus latro*. Previous biota sampling did not include this commonly harvested food, and concern exists regarding the potential for coconut crab to bioaccumulate heavy metal and organic soil contaminants. Sampling should be targeted toward crab harvest areas off base, especially any areas where there may be soil contaminated with metals and persistent organic compounds (e.g PCB).

PUBLIC HEALTH ACTION PLAN

The public health action plan (PHAP) for Andersen AFB contains a description of actions taken and those to be taken by ATSDR, the Air Force, EPA, and GEPA at and in the vicinity of the site subsequent to the completion of this public health assessment. The purpose of the PHAP is to ensure that this public health assessment not only identifies potential and on-going public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions at Andersen AFB that are completed or ongoing/planned are:

Completed Actions

1. The Air Force installed monitoring wells and has begun to identify groundwater plumes associated with Andersen AFB operations. Limited soil sampling and soil gas surveying has also been conducted.

2. Remedial actions are ongoing. In conjunction with Guam and Federal regulatory agencies, the Air Force has identified and implemented remedies at many of the 39 installation restoration program (IRP) sites at Andersen AFB. At several of the sites, remedial work is complete or no further action is required. Others are still undergoing investigation and remedial actions will be defined and implemented in the future. See Table 2 for details.

3. The Air Force has analyzed terrestrial biota to characterize ecological and human health hazards associated with the biaccumulation of contaminants in Guam plants and animals.

4. The Air Force has monitored and mitigated elevated radon levels in certain on-site housing units.

5. The Air Force has removed discarded drums containing asphalt and associated debris from Waste Pile 1. Confirmatory sampling indicates that SVOCs and PAHs in soil are below both EPA residential and industrial soil standards and that only relatively low levels of metals exist.

Ongoing and Planned Actions

1. The Air Force will continue its groundwater monitoring program. This program includes monitoring of municipal and private wells.

2. The Air Force will continue field investigations to characterize soil contamination at Andersen AFB.

3. The Air Force will continue to monitor and mitigate naturally occurring radon levels in on-base housing units.

4. The Air Force will continue to investigate any suspected discoveries of CAIS canisters, and associated contamination as needed. The Air Force has committed to work with territorial and Federal agencies and other DoD branches to ensure a timely and appropriate response to protect the health of Guam residents.

5. The Air Force will continue environmental investigations at the Urunao Dump sites, which are being proposed as IRP 40. If the data warrant, ATSDR will assess potential public health hazards on adjacent privately held land and modify conclusions in this document as needed.

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TABLES

Table 2. Summary of Exposure Pathways at Andersen Air Force Base

PATHWAY NAME	SOURCE OF CONTAMINATION	ENVIRONMENTAL MEDIUM	POINT OF EXPOSURE	ROUTE OF EXPOSURE	EXPOSED POPULATION	COMMENTS
Completed Exposure Pathways						

Groundwater in the vicinity of the MARBO Annex	Andersen AFB--TCE from the MARBO annex's WDBP site	Groundwater	Water supplied by two of the nine military production wells (MW-1 and MW-2) and the Tumon-Maui well.	Ingestion Dermal	**Past:** Military personnel, residents, and visitors drinking water from MW-1, MW-2, and the Tumon-Maui well No off-base populations were exposed **Current:** None **Future:** None	**Past:** ATSDR estimated past exposure to drinking water from MW-1 and MW-2 assuming exposure to the maximum detected concentration of TCE (9 ppb) and without accounting for dilution that occurs in the military distribution system. Estimated exposure doses were well below levels of health concern. ATSDR concluded that no apparent public health hazard exists from past exposure. **Current:** The Air Force installed air strippers to treat water from MW-1, MW-2, and the Tumon-Maui well. The Tumon-Maui well is currently closed. ATSDR concluded that no public health hazard is associated

						with TCE concentrations in the WDBP area (1 to 3 ppb) because current levels are below health-based guidelines and drinking water standards. Concentrations in the military distribution system are in the subpart per billion to nondetectable range. **Future:** No public health hazards are associated with potential future exposure to TCE. Groundwater monitoring will continue at all military production wells. Water from MW-2 will continue to be treated by the air strippers. If any other military wells contain contaminants detected above health-based guidelines, the use of the affected well will be discontinued. *Past, current, and future use of Andersen AFB drinking*

						water poses no apparent public health hazards.
Radon in on-base housing units	Naturally-occurring in Guam -- radon does not originate from military activities at Andersen AFB	Air	Indoor air in certain on-site housing units	Inhalation	Residents of base housing units.	**Past:** In 1993, The Air Force tested 1,652 family housing units: 867 units contained indoor air radon levels above EPA's recommended action level of 4 picocuries per liter (pCi/L) (124 contained radon above 120 pCi/L). The Air Force mitigated all radon contamination in these units to EPA's recommended action level. The full extent of past exposures is unknown; therefore, potential hazards associated with exposures is uncertain. Available information indicates *long-term* exposure to radon concentrations above 50 pCi/L have been associated with increased incidences of

						lung cancer. Most past exposures were likely much shorter. **Current:** The Air Force monitors and mitigates radon levels in on-base housing units and other structures. It is not known if people are exposed to radon levels above 4 pCi/L in on-site buildings because current, available data are incomplete. **Future:** The Air Force plans to expand its radon mitigation efforts to other, lower-priority buildings on base. If mitigation efforts continue as planned, people will most likely not be exposed to radon levels above 4 pCi/L in on-site buildings.

						Past exposure to radon in on-base family housing units at Andersen AFB poses indeterminate public health hazards. Current and potential future exposures are unlikely due to aggressive Air Force remediation efforts.
Potential Exposure Pathways						
Biota	Andersen AFB	Foods grown on base and game that graze on base	Consumption of foods and game	Ingestion	Residents, hunters and their families	No apparent public health hazard exists (past, current, or future) from the consumption of local biota collected on- or off-base at Andersen AFB. Most contaminants examined were below CVs or at levels below health concern. ATSDR concluded that the consumption of local biota poses no apparent public health hazard.
Soil	Andersen AFB IRP sites and areas of concern	Surface soil	Base IRP sites	Skin contact	Trespassers	No apparent public health hazard exists form past or current exposure

						because most sites are posted with signs and have restricted public access. Any infrequent and brief contact with soil that might occur during trespassing should not result in health effects. Certain sites will be transferred for public use. Deed restrictions and/or soil removal actions should prevent harmful exposure in the future.
Physical Hazards	UXO	UXO	Various sites in Northwest field	Detonation of UXO	Trespassers, recreational users	There have been no accidents or incidents involving unexploded ordnance. Education and UXO awareness program is in place. Area restrictions are communicated to recreational users. Incidental contact and resulting health hazards are remote.

Table 3. Summary of Radon Monitoring at Andersen Air Force Base

Sampling Year(s)	Sampling Locations	Number of Locations with Reported Indoor Air Radon Levels (pCi/L)				Comment
		< 4 pCi/L	4-20 pCi/L	20-200 pCi/L	> 200 pCi/L	
1987 and 1988	33 housing units	15	14	4	0	
1988 and 1989	1,406 housing units[1] (60 day sampler)	714	617	74	1	One-year samplers were deployed in the 617 homes with levels between 4 and 20 pCi/L until levels fell below 4 pCi/L. The 74 homes with radon levels greater than 20 pCI/L were mitigated and re-sampled to reduce radon levels.
1989	2,000 buildings [2] (1 year samplers)	824	851	85	0	The Air Force installed over-sized air conditioner fans to achieve positive pressure in the buildings.
1993	1,652 previously sampled housing units.	785	743	124	0	An Air Force contractor mitigated the 743 units with levels between 4 and 20 pCi/L. The Base Civil Engineering Squadron mitigated the 124 units with higher levels
1998	37 housing units (lacking pre and/or post-earthquake sampling and mitigation records.	26	8	0	0	The Air Force renovated three of the eight units that contained 4 to 20 pCi/L. Four of the five other units were previously renovated. The Air Force is reassessing mitigation designs at these units.
	35 non housing units	33	2	0	0	

[1] 1,745 samplers were placed in every on-site housing unit, but only 1,406 of the samplers were analyzed.
[2] Buildings sampled included housing units, dormitories, a child care center, the Chapel preschool, temporary lodging facilities, and unaccompanied officers quarters.

FIGURES

Figure 1. Area Map

Figure 2. Subbasins Underlying Andersen AFB

Figure 3. ATSDR's Exposure Evaluation Process

Figure 4a. Locations of the 39 IRP Sites

Figure 4b. Locations of the 39 IRP Sites Andersen AFB, Guam

Figure 5a. Locations of Suspected Groundwater Plumes

Figure 5b. Locations of Suspected Groundwater Plumes

Figure 6. General Regions of On- and Off-base Biota Sampling Collection

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PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM

APPENDIX A: EVALUATION OF POTENTIAL IRP SITES AT ANDERSON AFB

Site	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results*	Corrective Activities and/or Current Status	Evaluation of Public Health Hazards
Site No. 1 Landfill No. 1 (LF-1) (Operable Unit (OU): Main Base)	LF-1 opened in 1945 and continues to be used today as the base's only active landfill. Materials disposed of include sanitary trash, waste petroleum, oil, and lubricants (POL), solvents, ferrous metal, construction debris, and pesticides.	**Groundwater:** Trichloroethylene (TCE), tetrachloroethylene (PCE), chloroform, toluene, lead, and other organics were detected. Only lead was detected above Agency for Toxic Substances and Disease Registry (ATSDR) drinking water comparison values (CVs). **Soil**: Total petroleum hydrocarbons (TPH) and metals were detected.	**Corrective Activities**: The Air Force places soil cover on LF-1 daily. **Current Status:** LF-1 is still active and has been transferred to Resource Conservation and Recovery Act (RCRA) program.	**Groundwater**: No public health hazards are associated with LF-1. No drinking water wells are located in this area and none will be installed in the future. **Soil**: LF-1 is located in an industrial area not generally accessed by base personnel. Furthermore, a fence surrounds Andersen AFB and a gated entrance restricts access to the landfill; therefore, past, current, and future exposures to the general public are not expected.
Site No. 2 Landfill No. 2 (LF-2) Landfill No. 4 (LF-4) Landfill No. 5 (LF-	LF-4 and LF-5 are contained within LF-2. LF-2 was used from 1947 to 1975, with a small area remaining active until 1982. Materials disposed	**Groundwater:** TCE, PCE, toluene, lead, and other organics were detected. TCE was detected above the ATSDR CV. **Soil**: TPH, volatile organic compounds	**Corrective Activities**: Small area of LF-2 (all of LF-5) was capped as Remedial Action. **Current Status:** All other site areas in RI/FS process. LF-2 is inactive and currently	**Groundwater**: No public health hazards are associated with LF-2. No drinking water wells are located in this area and none will be installed in the future. **Soil**: LF-2 is located in

5) (OU: Main Base)	of at this site include sanitary trash, waste POL, solvents, pesticides, ferrous metal, construction debris, and unexploded ordinance (UXO).	(VOC), and metals were detected. Dioxins have also been detected at LF-2.	being remediated in conjunction with the lead stabilization of soils from MARBO and other asphaltic debris. The linear trenches will be covered with stabilized soil.	an industrial area not generally accessed by base personnel. Furthermore, a fence surrounds Andersen AFB and a gated entrance restricts access to the landfill. Currently, the site is overgrown with vegetation; therefore, past, current, and future exposures to the general public are not expected.
Site No. 3 Waste Pile No. 3 (WP-3) (OU: Main Base)	WP-3 was in use from 1947 to 1977. Materials disposed of include waste POL, solvents, industrial wastes, pesticides, sanitary trash, scrap metal, and construction debris.	**Groundwater:** TCE, chloroform, toluene, lead, and other organics were detected.No contaminants were detected above ATSDR CVs. **Soil**: TPH, VOCs, and metals were detected below ATSDR CVs for soil.	**Current Status:** WP-3 is a no further response action planned (NFRAP) site. The results of a risk assessment indicated that the levels of contaminants do not pose a threat to humans under industrial uses. Furthermore, the site has restricted access. Based on these factors, no further actions were recommended.	**Groundwater**: No public health hazards are associated with WP-3. No drinking water wells are located in this area and none will be installed in the future**.** **Soil**: No public health hazard is associated with soil at this site. The site has restricted access (and is considered as an industrial use site) and contaminants were detected at levels below health guidelines.
Site No. 4 Landfill No. 6 (LF-6) (OU: Main Base)	From 1953 to 1954, sanitary trash was disposed in LF-6.	**Groundwater:** No accessible groundwater flows beneath the site due to volcanic topography and no contaminants exceed EPA's MCLs in groundwater samples taken from a well located in a 0.5 mile radius of this site. **Soil**: Twenty surface soil samples were analyzed for VOCs, SVOCs, PAHs, and metals. Draft results indicate that aluminum, arsenic, manganese, and vanadium were detected at levels above CVs for a child but below CVs for an adult.	**Current Status:** NFRAP has been recommended for LF-6. A risk assessment indicated that levels of aluminum and manganese might pose concern for young children. The levels are consistent with background concentrations; therefore no further actions were recommended.	**Groundwater**: No public health hazard is associated with this site. No contaminants were detected above background concentrations. **Soil**: Access to LF-6 is restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 5	From 1956 to	**Groundwater:** No	**Current Status:**	**Groundwater**: No

Landfill No. 7 (LF-7) (OU: Main Base)	1958, sanitary trash was disposed in LF-7.	groundwater contamination has been associated with LF-7. **Soil**: Dioxin was detected at concentrations above CVs in surface soil. Elevated levels of lead were measured in subsurface soil.	In RI/FS process. LF-7 will be cleaned to remove "hot spots" of lead and dioxin.	public health hazard is associated with this site. **Soil**: Site No. 5 is not fenced and lies in the Cape Heart Housing Area built over LF-7, which was covered with clean surface fill material. Two or three houses might overlie the contaminated trenches. No public health hazards are associated with exposure to contaminated surface soil. No harmful exposures should occur in the future as lead-contaminated subsurface soil will be removed.
Site No. 6 Landfill No. 8 (LF-8) (OU: Main Base)	From 1946 to 1955, asphalt debris was disposed in LF-8.	**Groundwater:** Pesticides were detected in trace amounts. **Soil**: Semi-volatile organic compounds (SVOC) and pesticides were detected.	**Current Status:** LF-8 will be cleaned to remove residual PAHs that remained following the removal of asphalt in 1998.	**Groundwater**: No public health hazard is associated with this site. Contaminants were detected below ATSDR's drinking water CVs. **Soil**: Access to LF-8 is restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 7 Landfill No. 9 (LF-9) (OU: Northwest Field)	From 1949 to 1955, sanitary trash and concrete construction debris were disposed in LF-9. No areas of fill have been identified nor have areas of storage, release, or disposal of hazardous substances or petroleum products been known to have occurred at this site.	**Groundwater:** PCE, chloroform, toluene, xylene, and lead were detected in trace amounts. **Soil**: No evidence of past landfill activities were found during the initial site reconnaissance. No areas of fill were identified. Only a few areas of minor surface debris (none of it hazardous) were discovered.	**Current Status:** A NFRAP decision was recommended for this site based on the lack of data supporting the presence of a landfill at this location.	**Groundwater**: No public health hazard is associated with this site. Contaminants were detected below ATSDR's drinking water CVs. **Soil**: Quantitative data are limited, but no evidence of soil contamination was found at this site.
Site No. 8 Landfill No. 10 (LF-10) Landfill No. 11 (LF-11)	LF-10 operated from the early to mid-1950s. Materials disposed of included asphalt wastes, scrap	**Groundwater:** TCE, PCE, lead, and other organics were detected. PCE concentrations slightly exceeded the ATSDR drinking water	**Current Status:** LF10 (a,b,c) is under review. Remediation measures include capping, solidification, and soil removal.	**Groundwater**: No public health hazard is associated with this site. No production wells exist downgradient from the site and detected

Landfill No. 12 (LF-12) (OU: Main Base)	metals, empty 55-gallon drums, sanitary wastes, construction debris, occasional waste POL, and solvents. LF-11 was used in the early 1950s as a disposal area for asphaltic material, empty 55-gallon drums, and construction debris. LF-12 was used in the late 1950s to dispose of sanitary trash and small quantities of asphaltic wastes.	CV. **Soil**: SVOCs (up to 50 ppm) and pesticides were detected.		contaminants occurred outside the groundwater protection zone (GPZ). **Soil**: Access to this site is restricted; therefore, past, current, and future exposures to the general public are not expected. The site will continue to be used for industrial purposes in the future.
Site No. 9 Landfill No. 13 (LF-13) (OU: Main Base)	From 1951 to 1956, sanitary trash, equipment waste, POL, and unknown chemical wastes were discarded in LF-13.	**Groundwater:** No groundwater contamination has been associated with LF-13. **Soil**: ATSDR requested soil data, however data were not available for ATSDR's review.	**Current Status:** In RI/FS process.	**Groundwater**: No public health hazard is associated with this site. No contaminants were detected above background concentrations. **Soil**:No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 10 Landfill No. 14 (LF-14) (OU: Main Base)	During 1976, concrete debris and construction debris were disposed in LF-14.	**Groundwater:** No groundwater contamination has been associated with LF-14. **Soil**: SVOCs were detected below ATSDR CVs for soil. Lead was detected at levels up to 40,000 ppm.	**Current Status:** LF-14 is still being cleaned up but will still require additional characterization and most likely remediation of a subsurface waste pile.	**Groundwater**: No public health hazard is associated with this site. No contaminants were detected above background concentrations. **Soil**: No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 11	LF-15A was reportedly used in	**Groundwater:** No groundwater	**Corrective Activities**: In 1982, drums of paint	**Groundwater**: No public health hazard is

Landfill 15A Landfill 15B (OU: Main Base)	the late 1950s and early 1960s for sanitary trash and construction debris disposal. LF-15B was used in the 1960s for sanitary trash and debris. In the 1970s, solvents were disposed of in LF-15A. Drums of lead-based paint and solvents were discovered in LF-15B in 1981.	contamination has been associated with LF-15 or LF-16. **Soil**: SVOCs and metals were detected below ATSDR CVs for soil.	and solvents were removed. **Current Status:** LF-15 is a NFRAP site. Based on the results of a risk assessment that indicated no threats to human health and the lack of evidence to support the presence of a "landfill" or hazardous waste, no further actions were proposed for this site.	associated with this site. concentrations. **Soil**: No public health hazards are associated with soil at this site because contaminants were detected at levels below CVs.
Site No. 12 Landfill No. 17 (LF-17) Pati Point Dump (OU: Main Base)	From 1945 to 1949, LF-17 was used as a disposal area for sanitary trash and excess equipment (including trucks and airplane parts). Pati Point Dump contains trash, office furniture, NiCad batteries, and UXO. It is not known when Pati Point Dump was in use.	**Groundwater:** No groundwater contamination has been associated with LF-17. **Soil**: ATSDR requested soil data, however data were not available for ATSDR's review.	**Current Status:** In RI/FS process.	**Groundwater**: No public health hazard is associated with this site. concentrations. **Soil**:No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 13 Landfill No. 18 (LF-18) (OU: Main Base)	From 1967 to 1968, asphaltic waste and waste liquids were discarded in LF-18.	**Groundwater:** Pesticides were detected. **Soil**: Soil sampling is underway; therefore, the results are not yet available.	**Current Status:** In RI/FS process.	**Groundwater**: No public health hazard is associated with this site. No production wells exist downgradient from the site and detected contaminants occurred outside the GPZ. **Soil**: No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 14 Landfill No. 19 (LF-19)	In 1955, approximately 50 to 70 drums of asphalt were disposed in LF-19.	**Groundwater:** No groundwater contamination has been associated with LF-19. **Soil**: Soil sampling is	**Current Status:** In RI/FS process.	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health hazard is associated with

(OU: Main Base)		underway; therefore, the results are not yet available.		this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 15 Landfill No. 20 (LF-20) (OU: Main Base)	LF-20 contains sanitary trash from 1968.	**Groundwater:** No groundwater contamination has been associated with LF-20. **Soil**: ATSDR requested soil data, however data were not available for ATSDR's review.	**Current Status:** In RI/FS process.	**Groundwater**: No public health hazard is associated with this site. No contaminants were detected above background concentrations. **Soil**: No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 16 Landfill No. 21 (LF-21) (OU: Northwest Field)	From the mid-1950s to 1963, LF-21 operated as a sanitary trash disposal site.	**Groundwater:** No groundwater contamination has been associated with LF-21. **Soil**: VOCs and SVOCs were detected below ATSDR CVs for soil. Soil metals included cadmium (up to 240 ppm), chromium (up to 6,500 ppm), and lead (up to 16,000 ppm).	**Current Status:** Cleanup is in progress at LF-21. Further remediation includes the removal of additional hotspots of PAH- and metal- contaminated soil, testing of excavated area, and disposal either at the base landfill or an off island location.	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 17 Landfill No. 22 (LF-22) (OU: Northwest Field)	During the 1950s, sanitary trash and unknown quantities of UXO and black powder were discarded in LF-22.	**Groundwater:** No groundwater contamination has been associated with LF-22. **Soil**: Sixteen surface soil samples were analyzed for SVOCs, PAHs, metals, and cyanide. Draft results indicate that aluminum, cadmium, and manganese exceeded CVs for a child, but were below CVs for adults.	**Current Status:** LF-22 is a NFRAP site. Based on the results of a risk assessment that indicated none of the soil contaminant level posed unacceptable risks to human health, no further actions were proposed for this site.	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health hazard is associated with this site. Due to access restrictions no completed exposure pathway to site contaminants exists. The site will continue to be used for industrial purposes in the future.
Site No. 18 Landfill No. 23	LF-23 holds sanitary trash from operations in the late 1950s. No	**Groundwater:** No groundwater contamination has been associated with LF-23.	**Current Status:** LF-23 is a NFRAP site. Based on the lack of evidence to support the	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health

(LF-23) (OU: Harmon)	storage, release, or disposal of hazardous substances or petroleum products is known to have occurred at this site.	**Soil**: SVOCs and metals were detected below ATSDR CVs for soil.	presence of a "landfill" or hazardous waste, no further actions were recommended for this site.	hazards are associated with soil at this site. The site is generally inaccessible to the public and only low levels of contaminants were detected in soil.
Site No. 19 Landfill No. 24 (LF-24) (OU: Harmon)	LF-24 holds sanitary trash and possibly other types of debris from the 1950s.	**Groundwater:** No groundwater contamination has been associated with LF-24. **Soil**: SVOCs (up to 230 ppm), metals, and trace amounts of dioxins were detected. Only SVOC concentrations exceeded ATSDR CVs for soil.	**Current Status:** Cleanup is complete at LF-24.	**Groundwater**: No public health hazard is associated with this site. **Soil**: Access to this site was restricted; therefore, past exposures to the general public were not expected.
Site No. 20 Waste Pile No. 7 (WP-7) (formerly known as Landfill No. 25) (OU: MARBO Annex)	WP-7 was in use from 1945 to 1962. It contains sanitary trash, waste POL, solvents, scrap vehicles, and equipment, construction debris, and waste dry cleaning fluids.	**Groundwater:** TCE, PCE, 1,1,1-trichloroethane (TCA), carbon tetrachloride (CCl_4), toluene, xylene, lead, pesticides, and other organics were detected. TCE was detected slightly above the ATSDR drinking water CV. **Soil**: TPH and metals were detected in surface soil at levels below ATSDR CVs.	**Current Status**: As recommended in the ROD, the area was covered with clean fill to reduce the risk of exposure to contaminated soil.	**Groundwater**: No public health hazard is associated with WP-7 because no on-site production wells exist. WP-7 appears to be the source of TCE-contaminated groundwater in YU-2. **Soil**: No public health hazard is associated with soil at this site. The area is generally inaccessible to the public, only low levels of contaminants were detected, and the area has been covered with soil and vegetation.
Site No. 21 Landfill No. 26 (LF-26) (OU: Northwest Field)	LF-26 is filled with sanitary trash and construction debris from 1966.	**Groundwater:** Groundwater monitored at wells located 0.5 miles away indicate that no site contaminants exceeded CVs or MCLs. **Soil**: SVOCs (up to 42 ppm), metals, and dioxins were detected.	**Current Status:** LF-26 is a NFRAP site. Based on the results of a human health risk assessment indicating that exposure to surface soil would not increase the likelihood of cancer for residents, no further response actions were recommended.	**Groundwater**: No public health hazard is associated with this site because no on-site production wells exist. **Soil**: Access to LF-26 is restricted; therefore, past, current, and future exposures to the general public are not expected. No completed exposure pathway to site contaminants exists and no public health hazard is associated with this site.

Site No. 22 Waste Pile No. 6 (WP-6) (formerly known as Landfill No. 27) (OU: MARBO Annex)	WP-6 contains construction debris. Dates of operation are unknown.	**Groundwater:** PCE, toluene, lead, pesticides, and other organics were detected. Only PCE was detected above its respective ATSDR drinking water CV. **Soil**: TPH, VOCs, and metals (lead levels up to 6,500 ppm) were detected at levels above CVs. .	**Current Status:** Cleanup at WP-6 is in progress. The ROD selected soil removal as the preferred remedial alternative. Soil removal includes removal of asphalt drums, roofing material, and metal debris.	**Groundwater**: No public health hazard is associated with this site because no on-site production wells exist. WP-6 contributes to the PCE-contamination detected in YU-1 groundwater. **Soil**: Access to this site is restricted; therefore, past, current, and future exposures to the general public are not expected. Furthermore, no exposure to contaminated soil should occur in the future following the proposed soil removal measures, as recommended in the ROD.
Site No. 23 Waste Pile No. 5 (WP-5) (formerly known as Landfill No. 28) (OU: MARBO Annex)	WP-5 holds construction debris and auto bodies from unknown dates of operation.	**Groundwater:** PCE, toluene, lead, pesticides, and other organics were detected at levels below ATSDR's drinking water CVs. **Soil**: TPH and metals were detected below ATSDR CVs for soil.	**Current Status:** No health risks were found at WP-5; therefore no further action was recommended in the 1998 ROD for the MARBO Annex.	**Groundwater**: No public health hazard is associated with WP-5. All detected contaminants are below ATSDR's drinking water CVs. **Soil**: No public health hazard is associated with soil at WP-5. The site is inaccessible to the public and contaminants were detected in soil at levels below CVs.
Site No. 24 Landfill No. 29 (LF-29) (OU: MARBO Annex)	LF-29 is littered with household debris and garbage. Dates of operation are unknown.	**Groundwater:** Lead, pesticides, and other organics were detected in trace amounts. **Soil**: Trace amounts of VOCs were detected. Metal concentrations at LF-29 included antimony, chromium at 860 ppm and lead at 1,100 ppm at levels above CVs.	**Current Status:** LF-29 was covered with a uniform 2-foot layer of recemented limestone and several inches of soil and the surface of the landfill was vegetated. An estimated 13,000 cubic yards of lead- and antimony- contaminated soil is being excavated, treated to reduce leachability of the metals, and then transported to Andersen AFB Landfill for disposal..	**Groundwater**: No public health hazard is associated with LF-29. All detected contaminants are below ATSDR's drinking water CVs. **Soil**: Access to LF-29 is restricted; therefore, past, current, and future exposures to the general public are not expected. No completed exposure pathway to site contaminants exists, and no public health hazard is associated with this site.

Site No. 25 Fire Training Area No. 1 (FTA-1) (OU: Main Base)	From 1945 to 1958, waste solvents and contaminated fuels were used at FTA-1.	**Groundwater:** No groundwater contamination has been associated with FTA-1. **Soil**: Seven surface soil samples were analyzed for SVOCs, PAHs, pesticides, PCBs, and metals. Aluminum exceeded the CV for a child, but all other concentrations were below ATSDR's CVs for a child and adult.	**Current Status:** A NFRAP is recommend by the Air Force for this site based on the results of historical records search, document review, field investigations, and a risk assessment.	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health hazards are associated with soil at this site. The site is generally inaccessible to the public and only low levels of contaminants were detected in soil.
Site No. 26 Fire Training Area No. 2 (FTA-2) (OU: Main Base)	Between 1958 and 1988, contaminated JP-4, Mogas, diesel, waste POL, and solvents were spilled at FTA-2.	**Groundwater:** TCE and PCE were detected. BTEX (benzene, toluene, ethylbenzene, and xylene) were present at concentrations up to 7,200 ppb at levels above CVs. **Soil**: Dioxins (up to 19,000 ppm), VOCs (up to 109 ppm), SVOCs (up to 6.8 ppm), TPH, pesticides, and metals were detected at levels above CVs. .	**Corrective Activities**: The Air Force has not used FTA-2 since December 1988 due to closure by GEPA. **Current Status:** Bioventing will be used to remediate a subsurface plume of VOCs and BTEX compounds.	**Groundwater**: No public health hazard is associated with FTA-2 because no on-site production wells exist. FTA-2 is no longer in use, so toluene levels can be expected to decrease in the future. **Soil**: Access to FTA-2 is highly restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 27 Hazardous Waste Storage Area No. 1 (HW-1) (OU: Main Base)	Beginning in 1950 and continuing through the 1970s, POL and solvents were stored at HW-1. From the late 1970s to 1983, HW-1 was used to store hazardous wastes.	**Groundwater:** Groundwater data from downgradient wells have reported only trace amounts of VOCs (TCE). **Soil**: Trace amounts of VOCs and SVOCs were detected. Metals concentrations in surface soil were below background concentrations. Metal concentrations at HW-1 in the shallow subsurface soil included arsenic (up to 201 ppm), chromium (up to 1,300 ppm), and lead (up to 8,600 ppm) at levels above CVs.	**Current Status:** HW-1 is a NFRAP site. Site investigations indicate that no contaminants above residential soil standards exist in surface soil, ; therefore, no further response actions were recommended.	**Groundwater**: No public health hazard is associated with this site. **Soil**: Access to HW-1 is restricted and contamination was limited to the inaccessible subsurface soil; therefore, past, current, and future exposures to the general public are not expected.
Site No. 28 Chemical Storage	In the early 1970s, the site may have been used for the disposal of waste	**Groundwater:** No groundwater contamination has been associated with CS-1.	**Current Status:** CS-1is a NFRAP site.Based on the results of a human health risk	**Groundwater**: No public health hazard is associated with this site. **Soil**: No public health

Area No. 1 (CS-1) (OU: Main Base)	petroleum, oils, lubricants, and chlorinated solvents. About 70% of the site is filled material covered with vegetative cover.	**Soil**: SVOCs and PAHs were detected in low concentrations. Metals, including arsenic (up to 15 ppm) and lead (up to 770 ppm), exceeded CVs.	assessment indicating that exposure to surface soil would not increase the likelihood of non-cancer effects or cancer for residents, no further response actions were recommended.	hazard is associated with soil at CS-1. Although metals were detected in soil at levels above health-based guidelines, no exposure is occurring or is likely to occur. The site is generally inaccessible to the public due to heavy vegetative growth, which prevent contact with soil contamination.
Site No. 29 Waste Pile No. 2 (WP-2) (formerly known as Chemical Storage Area 2) (OU: Main Base)	Deteriorating drums of asphaltic tar are located at WP-2. Dates of operation are unknown.	**Groundwater:** TCE, PCE, toluene, lead, and other organics were detected in trace amounts. **Soil**: SVOCs were detected at levels up to 0.26 ppm. With the exception of chromium (up to 950 ppm) metal concentrations were below CVs.	**Current Status:** Cleanup is complete at WP-2.	**Groundwater**: No public health hazard is associated with this site. Contaminants were detected below ATSDR's drinking water CVs. **Soil**: Access to this site was restricted; therefore, past exposures to the general public were not expected. No current or future exposures are likely because contaminated media has been cleaned up at WP-2.
Site No. 30 Waste Pile No. 4 (WP-4) (formerly known as Chemical Storage Area 3) (OU: Northwest Field)	From 1950 to 1970, UXO was disposed in WP-4. In addition, the site was reportedly used for the disposal of waste oils and solvents.	**Groundwater:** Groundwater collected from downgradient monitoring wells contained VOCs and metals. Chromium and nickel possibly related to corrosion of the steel pump and screens in wells exceeded EPA's MCLs. **Soil**: PAHs were detected at levels up to CVs. Chromium concentrations in soil reached 2,200 ppm, levels above CVs.	**Current Status:** WP-4 is a NFRAP sites. A risk assessment indicated that exposure to surface soil posed non-cancer and cancer risk for trespassers and potential future residents. However, soil contaminant concentrations were consistent with regional background concentrations; therefore, no further response actions were recommended.	**Groundwater**: No public health hazard is associated with this site. Contaminants were detected below ATSDR's drinking water CVs. **Soil**: Access is restricted to assigned military personnel or authorized visitors and currently no people work or live on or near the site. Furthermore, the soil at the site is covered with mixed vegetation. Therefore, past, current, and future exposures to the general public are not expected.
Site No. 31 Chemical Storage Area No. 4 (CS-4)	From 1952 to 1956, waste oils and solvents were stored at CS-4.	**Groundwater:** No groundwater contamination has been associated with CS-4. **Soil**: Dioxins (up to 130	**Current Status:** Cleanup is in progress at CS-4. Approximately 420 cubic yards of lead-contaminated soils will	**Groundwater**: No public health hazard is associated with this site. **Soil**: Access to this site is restricted; therefore,

(OU: Northwest Field)		ppm), VOCs (up to 1 ppm), TPH, and lead (up to 3,100 ppm) were detected at levels above CVs.	be excavated and disposed of.	past, current, and future exposures to the general public are not expected.
Site No. 32 Drum Storage Area No. 1 (DS-1) (OU: Main Base)	DS-1 is an vehicle wash area, landfill, and drum storage area for POL products and solvents. The area consists of a 1-acre square asphalt foundation equipped with a vehicle wash rack and drainage system, leach field, and dump pit bounded by chain link fencing.	**Groundwater:** No groundwater contamination has been associated with DS-1. **Soil**: SVOCs and pesticides were detected.	**Current Status:** DS-1 is still active and was transferred to the Environmental Compliance Program Upon transfer, the IRP made recommendations for further soil sampling.	**Groundwater**: No public health hazard is associated with this site. **Soil**: Access to DS-1 is highly restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 33 Drum Storage Area No. 2 (DS-2) (OU: Main Base)	DS-2 is an active drum storage area for asphalt, paint, oil, tar, and contaminated soil from underground storage tank (UST) removals. It is about 4,000 feet from the nearest housing and is fenced. No evidence exists that the area was used for storage of hazardous substances before 1984.	**Groundwater:** TCE, PCE, lead, and other organics were detected. PCE concentrations slightly exceeded the ATSDR drinking water CV. **Soil**: Pesticides were detected.	**Current Status:** DS-2 is still active and was transferred to the Environmental Compliance Program because of the lack of evidence suggesting that hazardous material was present at the site prior to 1984. Upon transfer, the IRP made recommendations for further assessment of the site.	**Groundwater**: No public health hazard is associated with this site because no production wells are located in this area and no one is exposed to contaminated groundwater. **Soil**: Access to DS-2 is highly restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 34 PCB Storage Area (OU: Main Base)	The PCB Storage Area is no longer in use, but its dates of operation are unknown. This area was used for storage purposes and for the removal of oil from electrical equipment.	**Groundwater:** No groundwater contamination has been associated with the PCB Storage Area. **Soil**: SVOCs (up to 2 ppm) and PCB (up to 19 ppm) were detected at levels above CVs.	**Current Status:** Cleanup is in progress at the PCB Storage Area.	**Groundwater**: No public health hazard is associated with this site. No contaminants were detected above background concentrations. **Soil**: Access to the site is highly restricted; therefore, past, current, and future exposures to the general public are not expected. No completed exposure

				pathway exists.
Site No. 35 Waste Pile No. 1 (WP-1) (OU: Main Base)	Several thousand deteriorated drums of asphaltic tar from unknown dates are located at WP-1.	**Groundwater:** TCE, PCE, toluene, lead, pesticides, and other organics were all detected below ATSDR drinking water CVs. **Soil**: Dioxins (up to 87 ppm), SVOCs (up to 0.27 ppm), TPH, and metals (chromium levels up to 1,550 ppm) were detected at levels above CVs.	**Current Status**: Asphalt removal and excavation began in 1997. Drums containing asphalt material were emptied into trenches. Asphalt in about 3,000 drums has been processed and recovered at an on-site asphalt recovery system. About 3,000 cubic yards of asphalt debris and about 8,000 drums remain stockpiled at the site. A pilot study was planned to evaluate the disposal of the remaining debris.	**Groundwater**: No public health hazard is associated with this site. Contaminants were detected below ATSDR's drinking water CVs. **Soil**: No public health hazard is associated with soil at this site. Confirmatory soil sampling conducted after asphalt debris removal activities found no elevated levels of organic compounds. **Physical Hazards:**Due to site access restrictions, no hazards exists to the general public. Only trained personnel conducting work in accordance with OSHA requirements for health and safety are allowed access.
Site No. 36 Ritidian Waste Pile (OU: Northwest Field)	The dates of operation and contents of the Ritidian Waste Pile are unknown.	**Groundwater:** No groundwater contamination has been associated with the Ritidian Waste Pile. **Soil**: Soil sampling is underway; therefore, the results are not yet available.	**Current Status:** An EE/CA is underway.	**Groundwater**: No public health hazard is associated with this site. **Soil**: Access to LF-36 is restricted; therefore, past, current, and future exposures to the general public are not expected. However, ATSDR will review soil data when available to further assess potential public health hazards.
Site No. 37 War Dog Borrow Pit (WDBP) (OU: MARBO Annex)	WDBP is an abandoned quarry. Its dates of operation and contents are unknown.	**Groundwater:** TCE was detected above the ATSDR drinking water CV. PCE, TCA, chloroform, toluene, xylene, lead, and other organics were detected in trace amounts. **Soil**: TPH (dioxin levels up to 94 ppm) and metals were detected were detected at levels above CVs. .	**Current Status:** NFRAP.	**Groundwater**: No apparent public health hazard is associated with this site. TCE concentrations are diluted by the military's water distribution system. No public or private production wells are or have been contaminated by TCE from WDBP, and all other detected contaminants are below

				ATSDR's drinking water CVs. **Soil**: Access to WDBP is highly restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 38 MARBO Laundry Facility (MLF) (OU: MARBO Annex)	The MARBO Laundry Facility is a former laundry facility.	**Groundwater:** PCE was detected above the ATSDR drinking water CV. TCE, CCl_4, chloroform, toluene, xylene, lead, pesticides, and other organics were detected in trace amounts. **Soil**: TPH (dioxin levels up to 120 ppm) and metals (lead levels up to 15,700 ppm) were detected at levels above CVs.	**Current Status:** Cleanup is complete at MLF.	**Groundwater**: No public health hazards are associated with PCE-contaminated groundwater underlying the MARBO Laundry Facility because no production wells are located in this area and no one is exposed to contaminated groundwater. The MARBO Laundry Facility appears to be the main source of the YU-1 plume that may potentially contaminate downgradient production wells with PCE. Other chemicals concentrations at this site remain below ATSDR's drinking water CVs and are not associated with any public health hazards. **Soil**: Access to this site was restricted; therefore, past exposures to the general public were not expected. No current or future exposures are likely because contaminated soil has been cleaned up at MLF.
Site No. 39 Harmon Substation (OU: Harmon)	The dates of operation and waste contents at the Harmon Substation site are unknown.	**Groundwater:** No groundwater contamination has been associated with the Harmon Substation. **Soil**: Dioxins (up to 0.78 ppm), VOCs (up to 9.8 ppm), SVOCs (up to 1.8 ppm), pesticides (up to 12 ppm), and metals (chromium levels up to 830 ppm) were	**Current Status:** Cleanup is complete at HSS.	**Groundwater**: No public health hazard is associated with this site. **Soil**:Access to this site was restricted; therefore, past exposures to the general public were not expected. No current or future exposures are likely because contaminated media has been cleaned up at HSS.

		detected,some at levels above at CVs.		

Sources: SAIC 1991; USAF 1992a, 1996, 1997, 2000. Andersen AFB 1998b, 1998c, 1998d; Andersen AFB 1999c, 1999d, 1999e, 1999f, 1999g; Andersen AFB 2000b, 2000c.
*Groundwater results are for monitoring and production wells located immediately downgradient of each site.

APPENDIX B: GLOSSARY

Background Level:
A typical or average level of a chemical in the environment. *Background* often refers to naturally occurring or uncontaminated levels.

Biota:
Plants or animals. Refers to those organisms collected and hunted for food.

Carcinogen:
Any substance that may produce cancer.

Comparison Values:
Estimated contaminant concentrations in specific media that are not likely to cause adverse health effects, given a standard daily ingestion rate and standard body weight. The *comparison values* are calculated from the scientific literature available on a contaminant's exposure and health effects.

Concentration:
The amount of one substance dissolved or contained in a given amount of another. For example, sea water contains a higher concentration of salt than fresh water.

Contaminant:
Any substance or material that enters a system where it is not normally found or found in greater concentrations than background levels.

Dose:
The amount of substance to which a person is exposed. *Dose* often takes body weight into account.

Environmental contamination:

The presence of hazardous substances in the environment. From the public health perspective, *environmental contamination* is addressed when it potentially affects the health and quality of life of people living and working near the contamination.

EPA's Reference Dose (RfD):
An estimate of the daily exposure to a contaminant unlikely to cause non-carcinogenic adverse health effects over a lifetime of exposure. Like ATSDR's MRL, EPA's RfD is a dose expressed in mg/kg/day.

Exposure:
Contact with a chemical by swallowing, by breathing, or by direct contact (such as through the skin or eyes). *Exposure* may be short term (acute) or long term (chronic).

Hazard:
A source of risk that does not necessarily imply potential for occurrence. A hazard produces risk only if an exposure pathway exists, and if exposures create the possibility of adverse consequences.

Indeterminate Public Health Hazard:
The designation given to sites for which no conclusions about public health hazards can be made because data are lacking.

Ingestion:
Swallowing (such as eating or drinking). Chemicals can get in or on food, drink, utensils, cigarettes, or hands where they can be ingested. After *ingestion*, chemicals can be absorbed into the blood and distributed throughout the body.

Maximum Contaminant Levels (MCLs):
MCLs are legal drinking water quality standards defined by the Safe Drinking Water Act. MCLs represent contaminant concentrations in drinking water that someone could be exposed to on a daily basis over a life time without adverse health effects.

Media:
Soil, water, air, plants, animals, or any other parts of the environment that can contain contaminants.

Minimal Risk Level (MRL):
An *MRL* is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncancer) over a specified duration of exposure. *MRLs* are derived when reliable and sufficient data exist to identify the target

organ(s) of effect or the most sensitive health effect(s) for a specific duration via a given route of exposure. *MRLs* are based on noncancer health effects only. *MRLs* can be derived for acute, intermediate and chronic duration exposures by the inhalation and oral routes.

National Priorities List (NPL):
EPA's listing of sites that have undergone preliminary assessment and site inspection to determine which locations pose an immediate threat to persons living or working near the release. These sites are most in need of cleanup.

No Apparent Public Health Hazard:
The designation given to sites where human exposure to contaminated media is occurring or has occurred in the past, but the exposure is below a level of health hazard.

Plume:
An area of chemicals in a particular medium, such as air or groundwater, moving away from its source in a long band or column. A *plume* can be a column of smoke from a chimney or chemicals moving with groundwater.

Potentially Exposed:
The condition where valid information, usually analytical environmental data, indicates the presence of contaminant(s) of a public health concern in one or more environmental media contacting humans (e.g., air, drinking water, soil, food chain, surface water), and there is evidence that some of those persons may have an identified route(s) of exposure (e.g., drinking contaminated water, breathing contaminated air, having contact with contaminated soil, or eating contaminated food).

Public Health Assessment:
The evaluation of data and information on the release of hazardous substances into the environment in order to assess any current or future impact on public health, develop health advisories or other recommendations, and identify studies or actions needed to evaluate and mitigate or prevent human health effects; also, the document resulting from that evaluation.

Public Health Hazard:
Sites that pose a public health hazard as the result of long-term exposures to hazardous substances.

Reference Concentration (RfC):
A concentration in air expected to be associated with no deleterious health effects over a lifetime of exposure, assuming default body weights and inhalation rates.

Risk:

The probability that something will cause injury, combined with the potential severity of that injury.

Route of Exposure:

The path in which a person may contact a chemical substance. For example, drinking (ingestion) and bathing (skin contact) are two different *routes of exposure* to contaminants that may be found in water.

Volatile organic compound (VOC):

Substance containing carbon and different proportions of other elements such as hydrogen, oxygen, fluorine, chlorine, bromine, sulfur, or nitrogen; these substances easily become vapors or gases. A significant number of the VOCs are commonly used as solvents (e.g., paint thinners, lacquer thinner, degreasers, dry cleaning fluids).

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PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM

APPENDIX C: ATSDR'S EXPOSURE EVALUATION PROCESS

Estimates of Human Exposure Doses and Determination of Health Effects

Deriving Exposures Doses

After identifying contaminants in site media above comparison values, ATSDR further evaluates exposures to these contaminants considering information about exposures combined with scientific information from the toxicological and epidemiological literature. If necessary, ATSDR estimates exposure doses, which are estimates of how much contaminant a person is exposed to on a daily basis. Variables considered when estimating exposure doses include the contaminant concentration, the exposure amount (how much), the exposure frequency (how often), and the exposure duration (how long).

The estimated exposure doses can be used to evaluate potential noncancer and cancer effects associated with contaminants detected in site media. When evaluating ***noncancer*** effects, ATSDR compares the estimated exposure dose to standard toxicity values, including ATSDR's minimal risk levels (MRLs) and the U.S. Environmental Protection Agency's reference doses (RfDs), to evaluate whether adverse effects may occur. The chronic MRLs and RfDs are estimates of daily human exposure to a substance that is likely to be without appreciable risk of adverse noncancer effects over a specified duration. The chronic MRLs and RfDs are conservative values, based on the levels of exposure reported in the literature that represent no-observed-adverse-effects levels (NOAEL) or lowest-observed-adverse-effects-levels (LOAEL) for the most sensitive outcome for a given route of exposure (e.g., dermal contact, ingestion). Uncertainty (safety) factors are applied to NOAELs or LOAELs to account for variation in the human population and uncertainty involved in extrapolating human health effects from animal studies. ATSDR also reviews the toxicological literature and epidemiology studies to evaluate the weight of evidence for adverse effects.

When evaluating the potential for ***cancer*** , ATSDR uses a weight of evidence approach to determine whether cancer effects are likely or not from an exposure to a toxic agent. In it's evaluation, ATSDR considers toxicologic and epidemiologic literature as well as cancer slope factors (CSF) that define the relationship between exposure doses and the likelihood of an increased risk of developing cancer over a lifetime. The CSFs are developed using data from animal or human studies and often require extrapolation from high exposure doses administered in animal studies to lower exposure levels typical of human exposure to environmental contaminants. The CSF represents a theoretical, upper-bound estimate of the probability of developing cancer at a defined level of exposure; therefore, they tend to be very conservative (i.e., overestimate the actual risk) in order to account for a number of uncertainties in the data used in extrapolation. ATSDR also considers the cancer effect levels (CELs) reported in the literature. The CEL is the lowest dose of a chemical in a study, or group of studies, that was found to produce increased incidences of cancer (or tumors) in animals.

Estimating Exposure Doses from Ingesting Drinking Water from Base Wells

VOCs have been detected in Andersen AFB water supply wells MW-1, MW-2, and the Tumon-Maui well at concentrations greater than ATSDR comparison values and EPA's maximum contaminant levels for drinking water. To determine whether exposure to these contaminants in the well water is related to adverse health effects ATSDR estimated exposure doses for people consuming water containing the highest measured concentrations in the wells (39 ppb of TCE and 10 ppb of PCE). The estimated exposure doses were then used to estimate potential noncancer outcomes.

In estimating to what extent people might be exposed to contaminants, ATSDR used "conservative" or safe assumptions about possible human exposure and any associated health effects. ATSDR assumed that a person drank the most contaminated well water. ATSDR also used conservative assumptions about how often people drink water and how much they drink. For example, ATSDR assumed that a typical adult drank 2 liters of water each day and weighed 70 kilograms (kg) and that a child drank 1 liter of water each day and weighed 10 kg. Because ATSDR does not know with certainty how long exposure may have occurred, ATSDR estimated an exposure period of 30 years for an adult and 6 years for a child to calculate maximum exposure doses. These assumptions likely overestimate actual exposure because water from the wells was blended with other water in the distribution system and military employees drinking the TCE- and PCE-contaminated water were unlikely to be exposed for

more than a year or two due to the relatively short duration of military duty stations. Furthermore, the actual exposure period was likely much shorter than 30 or 6 years, because the contaminated well was taken off line once the contamination was detected. The conservative assumptions, however, allow ATSDR to estimate the highest possible exposure dose and determine the corresponding health effects. Although ATSDR expects that few individuals, if any, were exposed to the highest levels of contamination, the "conservative" estimates are used to protect public health. Also, as a reminder, Guam residents and the general public did not use drinking water from the military supply system.

Noncancer: The resulting adult and child exposure doses for PCE are lower than its ATSDR MRL of 0.01 mg/kg/day. No chronic oral MRL or RfD is currently available for TCE. ATSDR recently withdrew the intermediate MRL and no chronic MRL or RfD exists for TCE. The study on which the intermediate MRL was based has been questioned because it contains certain flaws and limitations (e.g., the exact amount of TCE-contaminated water consumed by laboratory animals in the study is uncertain). For comparison, ATSDR reviewed the available toxicologic literature to determine possible adverse effects associated with exposure at doses estimated for this pathway. On the basis of this review, the exposure doses estimated for TCE by ATSDR are several orders of magnitude lower than the lowest doses reported in the toxicologic literature capable of producing noncancer effects in experimental animals administered oral doses of TCE (ATSDR 1997). Therefore, drinking water containing the highest detected levels of TCE and PCE reported in the wells is not likely to result in adverse noncancer effect.

Cancer: TCE and PCE have been shown to cause cancer in laboratory animals given large doses. The link between TCE or PCE and cancer in humans drinking water is controversial, however. Available studies are inconclusive and the data are inadequate to establish a link. EPA is currently reviewing the scientific literature pertaining to the carcinogenicity of TCE and PCE to determine its cancer classification. Some studies have shown that individuals drinking TCE-contaminated water with up to 220 ppb (a concentration over 24 times greater than the maximum level detected at Andersen AFB) suffered no increased incidence of cancer (Vartianinen et al. 1993; ATSDR 1997a, b).

ATSDR concludes that there is *no apparent public health hazard* associated with drinking water in the past from MW-1, MW-2, and the Tumon-Maui well.

Estimating Exposure Doses from Ingesting of Local Biota

Metals, pesticides, and SVOCs were measured in samples of crops grown or game grazing at Andersen AFB. People regularly consume papaya fruit and other edible fruit grown on and off base. Some Guam residents recreationally hunt game around Andersen AFB. ATSDR evaluated potential human health hazards associated with ingesting contaminated biota. Chemical exposure doses were estimated using conservative consumption rates for a 70 kg adult (2 grams per day of Sambar deer and monitor lizard; 20 grams per day of wild pig; and 340 grams per day of papaya) and exposure frequencies (365 days per year for a 30-year period).

Of all the chemicals analyzed, only arsenic (0.00044 mg/kg/day) exceeded its respective MRL (0.0003 mg/kg/day). No MRL or RfD exists for aluminum, an essential human nutrient. Aluminum concentrations in Guam biota, however, appeared elevated compared to normal background concentrations. Aluminum concentrations in on-base deer and pig tissue were slightly above normal

background concentrations in mammals (1 to 5 ppm) as reported by Puls (1989), but detected concentrations in off-base deer and pig tissue were within normal background levels. ATSDR further examined the toxicologic literature to evaluate whether health effects were likely to occur at the detec ted levels of arsenic and aluminum.

Arsenic

ATSDR found that the estimated exposure doses for consumption of on-base produce were approximately 30 to 100 times lower than the lowest observed effect levels for chronic, oral doses of arsenic in humans (ATSDR 1993). Additionally, several epidemiologic studies of chronic, oral arsenic exposure report no health effects at average chronic doses of 0.0004-0.01 mg/kg/day (Mazumder et al. 1988; Valentine et al. 1985; Cebrian et al. 1983; Southwick et al. 1981; Harrington et al. 1978). It should be noted that estimated exposure doses and excess cancer risk were evaluated assuming that all produce (fruits and vegetables) consumed by Guam residents contained arsenic levels equal to the maximum arsenic level detected in on-base papaya. This assumption likely overestimates actual exposure. Access to Andersen AFB is restricted and no on-base areas are commercially farmed. Most residents, therefore, probably obtain their fruits and vegetables from areas not grown on Andersen AFB property. No off-base papaya samples had detectable levels of arsenic in their edible parts. The consumption of produce grown off-base, therefore, would not pose a public health threat. The estimated exposure dose from ingesting arsenic in on-base produce (0.00044 mg/kg/day) only slightly exceeds ATSDR's chronic oral MRL of 0.0003 mg/kg/day.

Aluminum

Aluminum non- and off-base papaya slightly exceeded background concentrations in unprocessed produce (0.1 to 7.16 ppm) as determined by Schenck et al. (1989). All monitor lizard aluminum concentrations were elevated. Over three-fourths of exposure to aluminum in local biota results from the ingestion of monitor lizard tissue. No island residents claimed, however, to eat monitor lizard when asked during the Guam diet survey (EA Engineering 1995). Therefore, exposure from the consumption of monitor lizard tissue appears unlikely, and, if it occurs at all, limited.

Due to restricted access to base properties, public exposure to contaminants from local biota is more likely to result from the consumption of off-base food sources. The estimated cumulative exposure to aluminum from analyzed off-base biota sources (0.0036 mg/kg/day) is 10 times lower than exposure from on-base biota.

The toxic potential of aluminum is extremely low compared to many other metals (ATSDR 1997c). If aluminum is chronically ingested, it may interfere with the body's up-take of calcium and phosphorous, however, the retention of aluminum in healthy mammals, specifically those without kidney dysfunction, is minimal. Even when dietary levels are high, aluminum concentrations in tissues do not reflect this increased exposure because most aluminum is excreted in the feces (ATSDR 1997c). Therefore, ATSDR concludes that aluminum is not likely to pose a noncancer public health hazard.

The EPA has not classified aluminum for human carcinogenicity, but ATSDR found no studies regarding cancer in humans after oral exposure to aluminum or aluminum compounds (ATSDR

1997c). Therefore, ATSDR concludes that exposure to aluminum in Guam biota will not pose a carcinogenic public health hazard.

Using current toxicologic information, ATSDR concludes that there are *no apparent health hazards* (past, current, or future) associated with consumption of local biota.

Evaluation of Radon Exposure

According to EPA, exposure to radon is a national environmental health problem and is not isolated to Guam (EPA 1992). Elevated radon levels have been discovered in virtually every state (Air Chek 1998). The EPA estimates that as many as 8 million homes throughout the country have elevated levels of radon. To date, state surveys show that 1 out of 5 homes in the United States has elevated radon levels (above 4 pCi/L) (Air Chek 1998).

Toxicologic studies report that radon exposure causes no adverse health effects from short term exposure. The primary health concern associated with residential radon exposure is lung cancer, although there is currently no clear evidence that radon exposure causes lung cancer. A recent report from the National Research Council estimates that approximately 1 in 7 of all lung cancer deaths can be attributed to radon exposure, independent of smoking status, though these estimates are uncertain (BEIR VI 1999).

Many factors influence the risk of lung cancer resulting from radon exposure. Among these are the radon level, the duration of exposure, the time since initiation of exposure, the age of an exposed individual, and the individual's smoking habits. The combined effects of cigarette smoking and radon exposure place current and former smokers at particularly high risk for lung cancer.

Epidemiologic studies show that individuals working in certain industries susceptible to radon releases are at greatest risk, because they are often exposed to high levels of radon over an extended period of time. In one study, uranium miners exposed to radon levels of 50 to 150 pCi/L in air for about 10 years have shown an increased frequency of lung cancer (ATSDR 1990), though this study suffers from several weaknesses including lack of control for exposures to other agents that could contribute to lung cancer, such as silica and smoking. In the past, some housing units at Andersen AFB contained radon levels above 50 pCi/L, but the duration of exposure to these levels was probably closer to 2 years (not 10 years), the average tour length on Andersen AFB.

The most effective methods of lung cancer prevention are to reduce radon exposure and to modify other risk factors, such as smoking (ATSDR 1992). Fortunately, the Air Force has been actively mitigating on-base housing levels of radon since 1989. Andersen AFB plans to continue its radon testing and mitigation of residential units in the future, as well as expand its base program to other, lower priority buildings.

ATSDR was unable to fully assess potential health hazards (if any) associated with past radon exposure at Andersen AFB. First, the full extent of past radon exposure at Andersen AFB remains unknown due to limited historical sampling data. Second, ATSDR does not have health-based comparison values for radon and EPA has not identified an inhalation reference concentration for radon. Moreover, EPA's carcinogen assessment summary for radon (formerly determined a human

carcinogen) has been withdrawn pending further review. ATSDR found no clear evidence that long-term exposure to radon at levels that are normally present in the environment (1 to 3 pCi/L for average outdoor air levels) is likely to result in harmful health effects.

APPENDIX D: BIOTA TABLES

Table D-1.Chemical Concentrations Detected in Tissue (Muscle and Liver) of Sambar Deer (*Cervus unicolor*) Collected On-site Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Muscle				
Aluminum	7	85.7%	1.1-16.3	6.02
Cadmium	7	42.9%	0.12-0.25	0.109
Chromium	7	42.9%	0.26-0.39	0.186
Copper	7	100.0%	1.2-2.2	1.66
Manganese	7	100.0%	0.14-0.25	0.19
Nickel	7	14.3%	0.34-0.34	0.201
Silver	7	14.3%	0.15-0.15	0.058
Vanadium	7	14.3%	0.21-0.21	0.101
Zinc	7	100.0%	20.0-34.0	26.7
Liver				
Aluminum	7	71.4%	3.0-9.3	3.77
Cadmium	7	100.0%	0.1-0.67	0.323
Chromium	7	57.1%	0.18-0.64	0.265
Copper	7	100.0%	1.9-29.4	14.2
Lead	6	16.7%	0.24-0.24	0.0775
Manganese	7	100.0%	1.3-2.7	1.90
Nickel	7	28.6%	0.42-0.84	0.311
Selenium	3	66.7%	0.14-0.15	0.112
Silver	7	14.3%	0.29-0.29	0.0793
Vanadium	7	14.3%	0.19-0.19	0.104
Zinc	7	100.0%	25.0-53.6	30.6

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million

Table D-2.Chemical Concentrations Detected in Tissue (Muscle and Liver) of Sambar Deer (*Cervus unicolor*) Collected Off-site Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Muscle				
Aluminum	2	50.0%	2.8-2.8	1.68
Cadmium	2	50.0%	0.14-0.14	0.0925
Chromium	2	50.0%	0.35-0.35	0.218
Copper	2	100.0%	1.4-75.6	38.5
Manganese	2	100.0%	0.77-2.6	1.69
Zinc	2	100.0%	15.2-25.5	20.4
Liver				
Aluminum	2	100.0%	2.3-2.7	2.50
Cadmium	2	50.0%	0.14-0.14	0.095
Chromium	2	50.0%	0.35-0.35	0.225
Copper	2	100.0%	1.7-16.70	9.20
Manganese	2	100.0%	0.29-2.3	1.30
Zinc	2	100.0%	22.3-25.4	23.9

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million

Table D-3. Chemical Concentrations Detected in Tissue (Muscle and Liver) Samples of Wild Pigs (*Sus scrofa*) Collected On-site Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Muscle				
Aluminum	8	100.0%	1.7-6.8	3.69

Cadmium	8	12.5%	0.23-0.23	0.0675
Chromium	8	87.5%	0.18-0.72	0.351
Copper	8	100.0%	0.31-1.1	0.756
Manganese	8	87.5%	0.08-0.17	0.128
Nickel	8	37.5%	0.67-0.9	0.413
Silver	8	50.0%	0.11-0.63	0.154
Vanadium	8	37.5%	0.3-0.66	0.225
Zinc	8	100.0%	16.8-23.8	19.4
DDE	8	12.5%	0.0037-0.0037	0.00191
4-Methylphenol	5	40.0%	0.034-0.037	0.113
Liver				
Aluminum	8	100.0%	3.7-34.3	11.8
Antimony	8	37.5%	0.08-0.33	0.0856
Cadmium	8	100.0%	0.26-3.6	1.08
Chromium	8	100.0%	0.13-0.48	0.298
Copper	8	100.0%	2.2-4.7	3.14
Lead	5	80.0%	0.12-0.16	0.112
Manganese	8	100.0%	1.4-3.0	2.09
Mercury	8	62.5%	0.1-0.27	0.127
Nickel	8	37.5%	0.4-1.1	0.349
Selenium	5	100.0%	0.12-0.53	0.292
Silver	8	12.5%	0.05-0.05	0.0406
Vanadium	8	37.5%	0.18-0.21	0.116
Zinc	8	100.0%	25.1-83.3	46.1
DDE	8	25.0%	0.0072-0.022	0.00489
Endosulfan sulfate	8	12.5%	0.0045-0.0045	0.00201
Endrin	8	12.5%	0.0065-0.0065	0.00226
4-Methylphenol	5	80.0%	0.14-0.38	0.217

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million

Table D-4. Chemical Concentrations in Samples of Wild Pigs (*Sus scrofa*) Collected Off-site, Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Muscle				
Aluminum	1	100.0%	NA	2.0
Antimony	1	100.0%	NA	0.27
Copper	1	100.0%	NA	0.58
Nickel	1	100.0%	NA	0.53
Zinc	1	100.0%	NA	21.4
Liver				
Antimony	1	100.0%	NA	0.11
Cadmium	1	100.0%	NA	0.13
Copper	1	100.0%	NA	36.0
Manganese	1	100.0%	NA	2.7
Selenium	1	100.0%	NA	1.3
Zinc	1	100.0%	NA	29.4

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million
NA = not applicable

Table D-5. Chemical Concentrations Detected in Whole Body (Heads Were Removed Prior to Analysis) Samples of Monitor Lizards (*Varanus indicus*) Collected On-site Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Whole Body				
Aluminum	5	100.0%	23.4-332.0	113.0
Antimony	5	80.0%	0.12-1.6	0.56
Cadmium	5	80.0%	0.14-0.47	0.227
Chromium	5	100.0%	0.45-2.4	1.11
Copper**	5	100.0%	0.95-14.7	5.01
Lead**	4	100.0%	0.23-45.6	14.2

Manganese	5	100.0%	0.48-6.6	2.0
Mercury	5	40.0%	0.1-0.18	0.081
Nickel	5	100.0%	0.44-2.1	0.846
Silver	5	80.0%	0.14-0.78	0.394
Vanadium	5	40.0%	0.33-0.36	0.196
Zinc	5	100.0%	23.3-55.0	36.8
DDD	5	20.0%	0.038-0.038	0.00892
DDE	5	40.0%	0.0044-0.1	0.0219
DDT	5	20.0%	0.15-0.15	0.0313

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.
** Copper and lead values are biased since the animals were shot with copper-plated lead pellets.

ppm = parts per million

Table D-6. Chemical Concentrations Detected in Whole Body (Heads Were Removed Prior to Analysis) Samples of Monitor Lizards (*Varanus indicus*) Collected Off-site Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Whole Body				
Aluminum	2	100.0%	38.0-104.0	71.0
Antimony	2	100.0%	0.09-0.13	0.11
Cadmium	2	50.0%	0.08-0.08	0.065
Chromium	2	100.0%	0.48-0.98	0.73
Copper**	2	100.0%	0.71-0.92	0.815
Lead**	2	100.0%	0.11-0.16	0.135
Manganese	2	100.0%	0.62-2.7	1.66
Nickel	2	100.0%	0.62-0.67	0.645
Selenium	1	100.0%	0.19-0.19	ND
Silver	2	100.0%	0.12-0.47	0.295
Vanadium	2	100.0%	0.24-0.45	0.345
Zinc	2	100.0%	31.4-37.8	34.6
DDE	2	50.0%	0.029-0.029	0.0153

DDT	2	50.0%	0.0039-0.0039	0.00278
Dieldrin	2	50.0%	0.0036-0.0036	0.00263
Heptachlor epoxide	2	50.0%	0.0053-0.0053	0.00308

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.
** Copper and lead values are biased since the animals were shot with copper-plated lead pellets.

ppm = parts per million
ND = not detected

Table D-7. Chemical Concentrations Detected in Papaya (*Carica papaya*) Collected On-base Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Edible Tissue				
Aluminum	5	100.0%	1.4-8.2	5.22
Arsenic	5	20.0%	0.09-0.09	0.055
Chromium	5	40.0%	0.51-0.8	0.318
Copper	5	100.0%	0.93-8.7	3.07
Lead	3	33.3%	0.12-0.12	0.0717
Manganese	5	100.0%	1.3-3.9	2.54
Nickel	5	80.0%	0.54-0.97	0.637
Silver	5	40.0%	0.21-0.77	0.225
Vanadium	5	40.0%	0.54-0.68	0.3
Zinc	5	100.0%	3.0-10.1	5.84
Di-n-butyl phthalate	3	33.3%	0.036-0.036	0.122
Cyanide	5	20.0%	0.16-0.16	0.069

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million

Table D-8. Chemical Concentrations Detected in Papaya (*Carica papaya*) Collected Off-base Andersen AFB, Guam

Contaminant	Number of Samples	Detection Frequency	Concentration Range (ppm)	Mean* Concentration (ppm)
Edible Tissue				
Aluminum	3	100.0%	1.9-7.5	5.47
Chromium	3	67.7%	0.48-0.66	0.413
Copper	3	100.0%	0.61-1.1	0.937
Lead	3	33.3%	0.09-0.09	0.0617
Manganese	3	100.0%	1.0-1.3	1.17
Nickel	3	33.3%	1.0-1.0	0.457
Silver	3	67.7%	0.35-0.64	0.347
Vanadium	3	67.7%	0.4-0.77	0.423
Zinc	3	100.0%	2.7-3.0	2.9
Di-n-butyl phthalate	3	67.7%	0.035-0.04	0.08

Source: EA Engineering 1995

* The mean was calculated using censored data (nondetects were assumed to be equal to 50% of the reported detection limit) when the frequency of detection was less than 100%.

ppm = parts per million

APPENDIX E: RESPONSE TO PUBLIC COMMENT

The Agency for Toxic Substances and Disease Registry (ATSDR) released the Andersen Air Force Base (Andersen AFB) Public Health Assessment (PHA) on September 27, 2001, for public review and comment. That public comment period ended November 30, 2001. The following documents ATSDR's response to comments and questions received during the public comment period.

1. **Comment:** The commenter asked about health risks associated with eating coconut crab, a popular wildlife food trapped in the study area. The commenter is concerned that contaminants in soil, such as polychlorinated biphenyls (PCBs), accumulate in portions of the crab (the fatty tissue) that are eaten by local residents.

   Response: No data on coconut crabs were available for ATSDR's review during the preparation of this public health assessment. Despite the lack of data, ATSDR believes that people are not at risk of exposure to unhealthy levels of Andersen AFB-related contaminants when they consume coconut crabs. In making this determination, ATSDR reviewed relevant, supplemental information, including bioaccumulation data for other native biota, areas of soil contamination, and possible harvesting areas.

Both on-site and off-site wildlife data were available for Sambar deer, wild pig, snakes, and lizards. Although not specific to coconut crab, these data help us assess whether wildlife, in general, are accumulating contaminants from Andersen AFB and, if so, whether contaminants are accumulating at levels that might be harmful to the consumer. For all cases, ATSDR found no apparent health hazards associated with the wildlife as a source of food.

Several areas of soil contamination were noted at Andersen AFB, but PCBs were most often reported in soil at the Main Base. Access restrictions are enforced at sites on the Main Base, thus essentially preventing people from harvesting crabs in the areas of likely PCB contamination.

Together, this information suggests that the wildlife are not accumulating contaminants at levels of concern and the soil contamination and harvesting areas are not co-located. Still, if biota sampling is conducted in the future, ATSDR recommends as a prudent measure that the program include sampling of coconut crabs.

2. **Comment**: The commenter expressed concern about high levels of trichloroethylene (TCE) and tetrachloroethylene (PCE) in groundwater and the potential for future exposure and health risk. The commenter also questioned how much was known about the extent of groundwater contamination and whether actions will be taken in the future to further evaluate the extent and to remove contamination.

   Response: TCE and PCE have been detected in groundwater beneath Andersen Air Force Base, but ATSDR believes that sufficient regulatory mechanisms are in place to track groundwater contamination and prevent potential harmful exposures in the future.

   - The Air Force, Guam Environmental Protection Agency (GEPA), and U.S. Environmental Protection Agency (EPA), agencies overseeing remediation at the base, are well aware of the groundwater contamination issue at Andersen AFB. With GEPA and EPA oversight, Andersen Air Force Base (Andersen AFB) routinely collects groundwater samples from a network of groundwater monitoring wells to track groundwater contamination. Through this effort, Andersen AFB has identified the highest levels of TCE within base property, at the northwest side of the MARBO Annex (in the Yigo Subbasin) near the Waste Transfer Stations. Additionally, elevated levels of PCE have been measured in monitoring wells adjacent to the MARBO Annex laundry. Andersen AFB has committed to a long-term groundwater monitoring program to ensure that contamination does not threaten local or base water supplies in the future.

   - Andersen AFB has removed contaminated soil (and a potential source of TCE and PCE to the underlying groundwater) from certain areas of the MARBO Annex.

- Andersen and municipal suppliers are required by law to test water supplies for pollutants and to comply with GEPA and EPA drinking water standards. Past monitoring efforts revealed that volatile organic compound (VOC)- contamination had entered three Andersen base water supply wells. In response to this finding, Andersen withdrew two of the wells from service indefinitely. Air stripping units are in place to remove VOC contamination, however, if and when these wells are restored to service. (VOCs concentrations in the third well had dropped to levels well below ATSDR's comparison values and EPA's maximum contaminant levels.) Except for these wells, no other drinking water wells have been or are likely impacted by VOC contamination because either: (1) contamination is not present upgradient of the well or (2) contamination, though present upgradient of the active well, is at relatively low levels. Water from all other operating base wells and from nearby municipal water wells will continue to be tested to ensure that the water delivered to customers is safe for drinking.

- GEPA maintains a wellhead protection program to prevent contamination from entering drinking water wells. Under this program, GEPA curtails development within a 1,000-foot radius of a drinking water well and restricts installation of water supply wells on property impacted by TCE and PCE.

ATSDR believes that these collective measures will help protect the aquifer beneath Andersen AFB and safeguard the quality of drinking water for future use. **Table of Contents**