Final

Remedial Investigation Work Plan
Landfill Areas 1 and 2
Former Ramey Air Force Base
Aguadilla, Puerto Rico

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List of Acronyms

ABS	absorption factor
Accutest	Accutest Laboratories, Inc.
AF	adherence factor
AT	averaging time
atmosphere-m^3/mole	atmospheres per cubic meter per mole
AWQC	ambient water quality criteria
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
BNA	base neutral/acid extractable
BW	body weight
CFR	Code of Federal Regulations
cm/hour	centimeters per hour
cm^2	square centimeter
cm^2/second	square centimeters per second
cm^3/g	cubic centimeters per gram
CO	contracting officer
COPEC	chemical of potential ecological concern
COPC	chemical of potential concern
COR	contracting officer representative
CSEM	conceptual site exposure model
DA	dose absorbed
°F	degrees Fahrenheit
DRO	diesel range organics
E&E	Ecology & Environment, Inc.
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
EQB	Environmental Quality Board, Commonwealth of Puerto Rico
ET	exposure time
FI	fractional term
FOD	frequency of detection
g	gram

g/cm^3	grams per cubic centimeter
g/day	grams per day
g/kg	grams per kilogram
g/m^2-second	grams per square meter per second
GAF	gastrointestinal absorption factor
GRO	gasoline range organics
HI	hazard index
HQ	hazard quotient
IDW	investigation-derived waste
ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IT	IT Corporation
kg	kilogram
kg/m^3	kilograms per cubic meter
K_p	permeability coefficient
L/day	liters per day
LFG	landfill gas
$\mu g/m^3$	micrograms per cubic meter
m^2	square meter
m^3	cubic meter
m^3/day	cubic meters per day
m^3/hour	cubic meters per hour
m^3/kg	cubic meters per kilogram
m/s	meters per second
MDC	maximum detected concentration
mg/cm^2	milligrams per square centimeter
mg/cm^2-event	milligrams per square centimeter per event
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilograms per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
msl	mean sea level
OSHA	Occupational Safety and Health Administration

List of Acronyms *(Continued)*

OVA	organic vapor analyzer
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PID	photoionization detector
PM	project manager
ppm	parts per million
PRASA	Puerto Rico Aqueduct and Sewer Authority
QA	quality assurance
QC	quality control
RAFB	former Ramey Air Force Base
RBC	risk-based concentration
RBSL	risk-based screening level
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
RSL	regional screening level
SA	surface area
SAP	sampling and analysis plan
SF	slope factor
Shaw	Shaw Environmental, Inc.
SLERA	screening-level ecological risk assessment
SSHP	site-specific safety and health plan
SVOC	semivolatile organic compound
TAL	target analyte list
TCE	trichloroethene
TCLP	toxicity characteristics leaching procedure
TM	technical manager
TPH	total petroleum hydrocarbon
UCL	upper confidence limit on the arithmetic mean
UF	uncertainty factor

List of Acronyms *(Continued)*

URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
WP	work plan

1.0 Project Description

1.1 Introduction

Through Total Environmental Restoration Contract No. DACA21-96-D-0018, Task Order No. 0030, the Savannah District of the U.S. Army Corps of Engineers (USACE) retained Shaw Environmental, Inc. (Shaw) to prepare this work plan (WP) and conduct a remedial investigation (RI) for Landfill Areas 1 and 2 at the former Ramey Air Force Base (RAFB), Aguadilla, Puerto Rico. This WP has been prepared to support the RI activities and is a revision to the June 2000 WP prepared by IT Corporation (IT) (IT, 2000). The location of the RAFB is shown on Figure 1-1.

Figure 1-2 shows the locations of Landfill Areas 1 and 2. Landfill Area 1 is believed to cover approximately 6.2 acres on an 18-acre tract leased by the Puerto Rico Ports Authority to a local farmer who uses the land for grazing. Landfill Area 2 is believed to cover approximately 23 acres on a 65-acre tract leased by the Puerto Rico Ports Authority to another local farmer who uses the land for grazing and growing crops (Ecology and Environment, Inc. [E&E], 2001).

1.2 Purpose and Objectives

The objectives of this task order are to conduct an RI at Landfill Areas 1 and 2 to evaluate potential leachate releases, landfill-derived contamination, and leachate release contributions to any identified soil, groundwater, surface water, and sediment contamination in drainage ditches, sinkholes, and a pond. The primary objective will be to collect and analyze soil and groundwater samples to determine if past releases from the sites have resulted in contaminant concentrations above action criteria. Another objective will be to evaluate data from the investigation to determine the need for additional investigation and/or corrective action at the sites in accordance with the Environmental Quality Board, Commonwealth of Puerto Rico (EQB) (EQB, 1990).

1.3 Scope of Work

The scope of the RI for Landfill Areas 1 and 2 includes: conducting a document review; preparing a site-specific WP, which includes a field sampling plan and site-specific safety and health plan (SSHP); mobilizing and conducting the field investigation activities; and preparing the RI report.

2.0 Site Background and Existing Conditions

The RAFB is located north of the city of Aguadilla, on the extreme northwestern tip of the island of Puerto Rico. The approximately 4,357-acre Base was acquired by the U.S Government between 1939 and 1963 and was utilized as a fully operational Air Force Base until its deactivation in 1973 (USACE, 1999).

On March 1, 1974, ownership of most of the property was transferred to the Puerto Rico Industrial Development Company. Since March 1974, there have been numerous transfers of land parcels between U.S. Government agencies, between the government and private companies, and between the U.S. Government and local government agencies. The Base property is currently occupied by the Puerto Rico Ports Authority, the Puerto Rico National Guard, U.S. Customs, the U.S. Coast Guard, educational facilities, several privately owned businesses, and residential property (E&E, 2001). The runway and one hangar building are now operated by the Puerto Rico Ports Authority as the Rafael Hernandez Airport (USACE, 1999).

2.1 Site Description

The following sections briefly describe the conditions found at the RAFB.

2.1.1 Topography

The elevation at the RAFB ranges from 0 feet above mean sea level (msl) at the north and western coastlines to approximately 240 feet above msl. An escarpment is located on the north and west portions of the Base, producing a steep rise in elevation from sea level (the Atlantic Ocean) to approximately 175 feet above msl. The flightline portion of the Base is flat and higher than much of the facility, with an approximate elevation of 190 to 230 feet above msl (U.S. Geological Survey [USGS], 1960). Rough relief occurs in parts of the RAFB due to the chemical dissolution of the underlying limestone bedrock. This dissolution has produced such karst features as sinkholes, caves, *mogotes* (haystack hills), dead-end valleys, and many precipitous cliffs (USGS, 1976).

2.1.2 Climate

The climate at the RAFB is classified as tropical-maritime, with temperatures ranging from 74 degrees Fahrenheit (°F) in January to 80°F in July. The average annual precipitation is approximately 60 inches, with the rainy season occurring from May through December (USGS, 1976). Tropical systems occasionally drift over the area, producing heavy rainfall and occasional

flooding. The wind regime is generally under the influence of prevailing easterly trade winds but is also affected by land and sea breezes. In general, the strongest winds occur early in the afternoon and the lightest during the night. Usually, the wind is strongest in July and light in autumn (U.S. Department of Agriculture [USDA], 1975).

2.1.3 Regional Geology

The RAFB is located in the Coastal Plains physiographic region in the Mayaguez area. The coastal plains parallel nearly the entire northern coastline and include most of the area north of the towns of Aguadilla, Moca, San Sebastion, and Lares. The coastal plains are composed of alluvial and terrace deposits characterized as unstratified, fine- to medium-grained quartz sand, and light to moderate brown clays. These unconsolidated materials are between 0 and 100 feet thick (Monroe, 1969).

The surficial deposits are underlain by limestone of Miocene age and are located in a broad limestone belt that is Puerto Rico's best developed karst region. The geologic formation found beneath the coastal sediments is the Early Miocene Aymamon Limestone. The upper member of this formation is characterized as very pale orange to bright yellow chalk containing fossils and interbedded with hard, vuggy, very pale orange to white limestone, some of which is fossiliferous (Monroe, 1969). The lower member of the Aymamon consists of white to very pale orange, very pure fossiliferous limestone; it is generally indurated into finely crystalline, dense limestone and is locally a recemented solution breccia (Monroe, 1966; 1969). The Aymamon Formation is estimated to be up to 1,000 feet thick beneath the site (Rodriguez-Martinez, 1995). The middle and upper parts of the formation are highly permeable, with as much as 25 percent total porosity (Rodriguez-Martinez, 1995).

Underlying the Aymamon Limestone is the Aguada Limestone, which is characterized as a hard, thick-bedded calcarenite interbedded with chalky limestone and marl (Monroe, 1969). The Aguada Limestone is approximately 300 feet thick. The Aguada is underlain by the Cibao Formation. The Cibao Formation is approximately 700 to 870 feet thick and consists of interbedded calcareous clay; earthy chalk; hard, very fine-grained calcarenite; and soft, nongranular limestone (Monroe, 1969).

The RAFB is situated on the Aguadilla Uplift. This uplift has resulted in a northwest-plunging structural anticline with some faulting reported in the vicinity of the city of Aguadilla. The Base is situated on the east flank of the anticline, with the bedrock dipping to the northeast.

2.1.4 Local Geology

Unconsolidated soils encountered during the drilling activities conducted by E&E in 1996 at Landfill Areas 1 and 2 were visually characterized and consisted primarily of brown to orange-brown silty, sandy clay and sandy clay (E&E, 2001). At Landfill Area 2, where agricultural crops are grown, a thin (1- to 2-foot-thick) veneer of brown silt loam overlies the orange-brown silty, sandy clays and sandy clays.

Based on well borehole logs, bedrock was encountered in the landfills at depths ranging from 8 to 66 feet below ground surface (bgs). The Aymamon Limestone was described as a buff to yellow-tan, soft, moderately to heavily weathered, porous and pitted limestone with some iron staining (E&E, 2001). Hardness and color varies slightly with depth. Cuttings from various depths were also observed to contain fossils. Some travertine and clear calcite crystals were observed in rock cuttings at approximately 135 feet bgs at Landfill Area 1. Numerous voids were encountered during the air rotary drilling between 150 and 200 feet bgs, resulting in the loss of circulation at several well locations.

2.1.5 Soils

The majority of the soils at the RAFB are either of the Bejucos-Jobos Association or the Coto-Aceitunas Association (USDA, 1975). The Bejucos-Jobos Association is composed of strongly leached soils that have a tight, dominantly clayey subsoil. The majority of soils in this classification are well drained and strongly acidic. The Bejucos soils have a dark yellowish-brown, moderately coarse-textured surface layer and a subsoil that is dominantly fine textured and mottled below a depth of about 37 inches. The Jobos soils have a dark grayish-brown, coarse-textured surface layer and a thick, mottled, red and strong brown, compact, fine-textured subsoil.

The Coto-Aceitunas Association consists of slightly leached and strongly leached porous soils that are dominantly clayey throughout (USDA, 1975). The major soils of this association are underlain by hard, fragmented limestone and are characterized as deep, gently sloping to sloping, well drained and moderately permeable. The Coto soils are reddish brown, slightly acidic, and fine textured; the Aceitunas soils are dark reddish brown, fine-textured and moderately fine-textured, and very strongly acidic.

2.1.6 Local Hydrogeology

The North Coast Limestone aquifer system is composed of three hydrogeologic units: an upper water table aquifer, a middle confining unit, and a lower confined aquifer. The water table

aquifer consists of the Aymamon Limestone and the Aguada Limestone. The lower Aguada Limestone and the Cibao Formation form the middle confining unit. The lower confined aquifer is composed of the lower Cibao Formation. The lower aquifer is fragmented into several confined units in the western part and does not seem to be an important source of groundwater in the vicinity of the RAFB. The major hydrogeologic units of the aquifer system were based on the relative permeability and hydraulic continuity of the units (Rodriguez-Martinez, 1995).

The water table aquifer is contained in karst limestone bedrock. Most of the permeability of the aquifer is the result of secondary porosity caused by the dissolution of the bedrock along joints, fractures, and bedding planes. Because of the karst nature of the aquifer, water levels may fluctuate greatly (plus or minus tens of feet), thereby affecting groundwater flow direction and velocity. The transmissivities in the water table aquifer range from 200 to more than 280,000 square feet per day (Rodriguez-Martinez, 1995).

The water table aquifer is encountered at depths ranging from approximately 195 to 280 feet bgs in the vicinity of the RAFB and the town of Isabella. The water table aquifer in the area of northwestern Puerto Rico ranges in thickness from approximately 900 to 1,035 feet (Rodriguez-Martinez and Hartley, 1994).

The freshwater-saltwater interface was reported at a depth of approximately 190 feet below the top of the water table (455 feet bgs) at Isabella by Rodriguez-Martinez (1995). The freshwater-saltwater mixing zone is included in the saltwater zone. The landward extent of the saltwater zone is unknown in the western part of the limestone aquifer.

Groundwater at Landfill Area 1 was encountered between approximately 214 and 240 feet bgs and flowed toward the east. Groundwater at Landfill Area 2 was encountered between approximately 211 and 223 feet bgs and flowed north and northwest toward the ocean (E&E, 2001).

2.1.7 Surface Water Hydrology

Surface water at Landfill Area 1 drains toward an adjacent sinkhole along drainage channels. These narrow drainage channels are approximately 30 feet deep, with exposed bedrock at the bottom. There are swallows along the course of the channels, allowing for direct transport of storm water to the underlying groundwater. The easternmost channel has begun to expose landfill material, which is being transported into the sinkhole during storm events. Ponded storm

water can remain in the sinkhole for up to a week after a storm, and water marks as high as 12 feet have been observed in the sinkhole (E&E, 2001).

Inspection of a 1966 map of the Base indicates that the storm flow channels that received runoff from the aircraft apron terminated into a naturally occurring low area (E&E, 2001). The sanitary fill from the Base was placed in the low area as well. A comparison of the 1966 map with current conditions indicates that the sinkhole next to Landfill Area 1 has probably developed during the last 30 years and now is gradually capturing the western edge of Landfill Area 1.

2.1.8 Water Supply

Groundwater at the RAFB is classified as potable, and is considered a potential future source of drinking water. Potable water at the RAFB is currently supplied by the Puerto Rico Aqueduct and Sewer Authority (PRASA). PRASA reports that domestic water supply in the vicinity of the RAFB is obtained from several surface water reservoirs located between 5 and 10 miles south and southeast, and upgradient of the Base. A site visit and file review by E&E revealed no indication of private supply wells for domestic use (E&E, 2001). A water supply well used by U.S. Customs was discovered on a site visit by Shaw personnel. The RAFB did maintain a supply well (or wells) and a water tower for potable use, but this equipment has fallen into extreme disrepair and appears unusable (E&E, 2001). Mappable information for these wells is currently unavailable. However, a reasonable search will be made for them during field operations. If encountered, they will be surveyed, and their locations included on RI report figures.

2.2 Existing Conditions

Existing conditions at Landfill Areas 1 and 2 are described in the sections below. The waste depth and soil thickness are uncertain, and the results of geophysical studies conducted to-date are regarded as inconclusive, according to the EQB, because of unsuitable techniques and grid spacing.

The conditions extant at Landfill Areas 1 and 2 are such that the sites are potentially classifiable as jurisdictional wetlands. This potential exists for the drainage ditches and sinkhole at Landfill Area 1 and the pond and sinkhole adjacent to and north of, respectively, Landfill Area 2. The procedures required to make the jurisdictional wetlands determination are codified under the authority of USACE and are detailed in Section 5.2 of this WP.

Landfill Area 1. For the purposes of this WP, Landfill Area 1 consists of the former burial area, an adjacent sinkhole, and a small hill (Figure 2-1). Topographic relief in the area of Landfill Area 1 is approximately 70 feet and slopes toward the sinkhole immediately west of the disposal area. The sinkhole is approximately 35 feet deep and approximately 0.8 acre in size. A 1-acre hill is located immediately north of the landfill area, and an aircraft apron used to store inoperable and scrap aircraft is located north of the site. The burial area occupies an estimated 6.2 acres. Figure 2-1 shows the locations of the aircraft apron, the sinkhole, the hill, and the area where the sanitary waste was disposed. The time period or nature of disposal at this site has not been determined from existing records. However, a 1966 map of the Base refers to Landfill Area 1 as a "sanitary fill" area. An aerial photograph indicates that disposal was occurring in 1970, but this is the only information on disposal discovered to date. Figure 2-2 is an overlay of a 1983 aerial photograph on the Base map that shows both Landfill Areas 1 and 2.

Some of the landfilled material has become exposed at the surface due to erosion, especially along the western edge of the landfill. Construction debris and scrap metal are present on the ground surface and are believed to be present below grade. There has also been some public dumping of refuse south and east of the landfill area. Some medical waste of unknown origin has been observed in the sinkhole and is believed to have been transported into the sinkhole during storms. The medical waste appears to have been placed in fabric bags, then disposed of in the landfill. The medical waste includes intravenous bags and tubing, latex gloves, and syringes (E&E, 2001).

Landfill Area 2. Landfill Area 2 (Figure 2-3) is a flat-lying grass-covered tract currently used by a tenant for grazing and crop growing. No records of disposal activities at this site have been located to date. Two geophysical surveys were previously conducted at Landfill Area 2, one by USACE and one by E&E, but the results may not be conclusive because of techniques used and spacing of the sensors. Based on the geophysical surveys, the burial area for Landfill Area 2 occupies approximately 23 acres. Landfill Area 2 is reported to have received municipal household garbage from a former adjacent Air Force housing development called "Tropical Acres." There are several old building foundations that appear to have been built when the Base was operating (E&E, 2001). A pond was recently constructed by USACE and altered by the tenant farmer to use for drinking water for cattle. A broad shallow sinkhole is located about 200 feet north of the burial area. Surface runoff from a small part of the burial area drains into the sinkhole, but for the most part, the slope of the landfill area is toward the south.

2.3 Previous Investigation

The initial investigation of environmental conditions of Landfill Areas 1 and 2 took place in 1996 and 1997 and was conducted by E&E of Pensacola, Florida. During that investigation, nine groundwater monitoring wells were drilled and samples collected from each well. There are four existing wells at Landfill Area 1 and five at Landfill Area 2. Construction details of these wells are shown in Tables 2-1 and 2-2. Soil samples were collected during boring operations for the monitoring wells. Accordingly, the existing surface and subsurface soil analytical result locations are coincident with the existing monitoring well locations. The top 2 feet of the soil borings was used to assess surface soil conditions, and the remainder of the boring was used for subsurface soil assessment. Also, a sediment and surface water sample was collected from the sinkhole at Landfill Area 1. All samples were analyzed for volatile organic compounds (VOC), base neutral/acid extractables (BNA), total petroleum hydrocarbons (TPH) (including gasoline range organics [GRO] and diesel range organics [DRO]), target analyte list (TAL) metals, pesticides, and polychlorinated biphenyls (PCB).

Groundwater Sampling Results. Four groundwater samples collected from Landfill Area 1 were analyzed. Chloroform (RMW1-4, screened interval: 222-237 feet bgs) and trichloroethene (TCE) (RMW1-2, screened interval 229-244 feet bgs; RMW1-3, screened interval: 210-225 feet bgs; and RMW1-4) were detected at levels exceeding U.S. Environmental Protection Agency (EPA) Region 3 risk-based concentrations (RBC) (EPA, 2007a). Iron (RMW1-1, screened interval: 238-273 feet bgs), chloroform (RMW1-4), arochlor (RMW1-3), and TCE (RMW1-2, RMW1-3, and RMW1-4) were detected at levels exceeding EPA maximum contaminant levels. TCE (RMW1-2, RMW1-3, and RMW1-4) was detected at levels exceeding Puerto Rico ambient water quality criteria (AWQC). These results are shown in Tables 2-3 (inorganics) and 2-4 (organics). Five groundwater samples collected from Landfill Area 2 were analyzed. Chloroform (RMW2-1, screened interval: 220-235 feet bgs and RMW2-3, screened interval: 215-230 feet bgs) and bromodichloromethane (RWM2-1, screened interval: 220-235 feet bgs) were detected at levels exceeding EPA Region 3 RBC. Manganese, (RMW2-1) iron (RMW2-1; RMW2-2, screened interval: 205-220 feet bgs; and RWM2-3), and aluminum (RMW2-1) were detected at levels exceeding EPA maximum contaminant levels. No contaminants were detected at levels exceeding Puerto Rico AWQCs. The groundwater analytical results from Landfill Area 2 are provided in Tables 2-5 and 2-6 (E&E, 2001).

Surface Soil Sampling Results. Surface soil was sampled during drilling operations for the installation of groundwater monitoring wells at both Landfill Areas 1 and 2. The surface soil samples were collected from the first 2 feet in the soil boring for each of the nine wells. The

analytes that were detected above established threshold levels at both landfills were arsenic, iron, thallium, antimony, and chromium. One sample from Landfill Area 2 was slightly above the EPA Region 3 residential RBC for manganese. These detections may be naturally occurring concentrations of these constituents in native soils of the region. This will be determined upon evaluation of these concentrations versus those found in the background soil study (Shaw, 2004). The results of previous surface soil sample analyses are summarized in Tables 2-7, 2-8, 2-9, and 2-10 (E&E, 2001).

Surface Water and Sediment Sampling Results. One surface water sample and one sediment sample were collected during the initial investigation at Landfill Area 1 (Figure 2-1). No parameters were detected above Puerto Rico Water Quality Standards in the surface water sample. The analytes detected above screening values in the sediment sample were arsenic, magnesium, and three semivolatile organic compounds (SVOC). Tables 2-11 through 2-14 summarize the analytical results from the surface water and sediment sampling (E&E, 2001).

Subsurface Soil. Subsurface soil samples were collected from seven of the boreholes which were converted into groundwater monitoring wells. Subsurface soil samples were collected from 4 to 6, 9 to 11, and 15 to 17 feet at Landfill Area 1 (RMW1-1 and RMW1-4); and from 4 to 6, 9 to 11, 14 to 16, 19 to 21, 24 to 26, 29 to 31, and 34 to 36 feet at Landfill Area 2 (RMW2-1 through RMW2-5). The only constituents detected above the EPA Region 3 industrial RBCs were arsenic, total chromium, acetone, toluene, thallium, and carbon disulfide. The inorganic elements detected above RBCs may be naturally occurring. This will be determined when a comparison to the background soil study is conducted. Acetone is a common laboratory contaminant. During preparation of the risk assessment, quality assurance (QA)/quality control (QC) data will be scrutinized to determine if detected concentrations represent background levels. No VOCs, pesticides, or petroleum hydrocarbons were detected in subsurface soil samples. These analytical results are included in Tables 2-15 through 2-28.

3.0 Field Sampling Plan

An installation-wide sampling and analysis plan (SAP) (Shaw, 2006a) was prepared in accordance with the USACE-Savannah District SAP and EM200-1-3 (USACE, 2001). While specific references are made in this WP to the installation-wide SAP, work will be conducted in accordance with the USACE SAP.

The purpose of the RI at Landfill Areas 1 and 2 is to support a remedial decision for these areas by determining the presence and nature of potential contamination in groundwater, surface and subsurface soil, surface water, and sediment.

Samples from all media will be collected and submitted for chemical analysis. Sample locations will be adjusted as necessary based on existing site conditions. The results of these analyses will be used to prepare a baseline human health risk assessment (BHHRA) and screening-level ecological risk assessment (SLERA) for the landfill areas.

3.1 Data Collection Strategy

Data collected as part of this RI will be used to prepare risk assessments to determine what effects, if any, contaminants might have on humans and the environment. It is estimated that a total of 44 surface and a maximum of 64 subsurface soil samples will be collected and analyzed by an off-site laboratory. Groundwater samples will be collected from each of the nine existing monitoring wells at both landfills. A maximum of 6 collocated sediment/surface water samples will be collected from the landfills and sent for laboratory analysis.

Site geology and hydrogeology, as presently understood, suggest a strong vertical component to contaminant migrations. It is unknown whether the current well configuration is suitable to provide sentinel monitoring for lateral contaminant migration. Vertical migration directly beneath Landfill Areas 1 and 2 is currently unmonitored. Accordingly, groundwater flow studies will be conducted at Landfill Areas 1 and 2 to determine whether existing wells are sufficient in number and properly placed to intercept potential lateral or vertical migration of contaminants from the landfills..

3.1.1 Data Uses and Quality Assurance/Quality Control Sampling

The data collected in this sampling effort will be compared to background values to determine if there is a significant variance between background and the samples collected at Landfill Areas 1

and 2. If the presence of contamination is confirmed, risk assessments will be conducted to determine what effects, if any, the contamination might have on human health and the environment. The results of the risk assessments will determine the need for remedial action, further investigation, or a long-term monitoring decision.

The decision-making process for the data quality objectives is provided in Chapter 3.0 of the SAP (Shaw, 2006a). Sample analyses will be performed in an off-site fixed-base laboratory. All data collected will be required to meet the overall objectives of the RI. To ensure that the data meet these objectives, QA/QC samples will be collected during the field investigation. Frequencies of QA/QC samples will be those specified in the SAP. Table 3-2 defines the number of QA and QC samples to be collected. All QA/QC sampling will follow the requirements and procedures provided in Chapter 6.0 of the SAP.

Accutest Laboratories, Inc. (Accutest) will be utilized as the fixed-base analytical laboratory and will be responsible for conforming to laboratory procedures presented in Chapter 7.0 of the SAP (Shaw, 2006a). This program provides the methods and procedures that will assess the precision, accuracy, and completeness of the data. All data collected as part of the RI will be stored in an electronic database for future use. The specifics of the data management plan are provided in Chapter 8.0 of the SAP.

Table 3-1 presents the numbers of samples to be collected and the analytical methods to be performed for all samples collected during the RI of Landfill Areas 1 and 2. Table 3-2 presents the number of samples, including QA/QC samples, the sample bottles to be filled, and the sample hold time. Sample identification numbers were developed in accordance with procedures established in Chapter 6.0 of the SAP (Shaw, 2006a). The rationale for selection of sample analyses and sampling approach, and the sampling procedures that will be used during the RI are discussed in the following sections.

3.1.2 Rationale for Selection of Sample Analyses

Sampling is planned for all appropriate site media, including surface and subsurface soil, groundwater, surface water, and sediment.

In order to determine the presence of contamination at either landfill site, a series of surface and subsurface soil samples is proposed for each. The samples will be analyzed for VOCs, SVOCs (often referred to as BNA organic compounds), TAL metals, TPH-DRO, TPH-GRO, pesticides, and PCBs. In addition, up to three of the subsurface soil samples from Landfill Area 1 and up to

five of the subsurface soil samples from Landfill Area 2 will be analyzed for the presence of explosives and propellants, including analysis for perchlorate by Method 6850. These subsurface samples may also potentially be analyzed for the presence of dioxins and furans if planned test pit excavations reveal evidence of burned waste. Table 3-1 lists the numbers of samples to be collected at both Landfill Areas 1 and 2, the analytical methods for each sample, and the sample designations. These methods were chosen because they provide the most comprehensive set of constituents for analysis. This sample analysis strategy is necessary because the types of burial that took place at both landfills are uncertain.

Proposed groundwater sampling will include samples to be collected from water supply and U.S. Customs wells, in addition to landfill monitoring wells. Locations of these wells are presently unclear. However, a search will be made for them during the field effort, and all those located will be sampled. All groundwater samples will be analyzed for VOCs, SVOCs, pesticides, PCBs, TPH-PRO and TPH-GRO, TAL metals (total and dissolved), anion (chloride, sulfate, nitrate, phosphate, and fluoride), total dissolved solids, total suspended solids, and alkalinity.

3.1.2.1 Landfill Area 1

Geophysical Investigation and Test Pit Excavation A geophysical investigation of Landfill Area 1 will be conducted. This investigation will employ a combination of electrical resistivity and seismic refraction surveys to: determine the type and thickness of the landfill cover, the horizontal and vertical extent of waste burial, the location of subsurface anomalies, the nature of the bedrock surface underlying waste and overburden, and to detect voids and conduits within the bedrock that may affect contaminant transport. These surveys will focus primarily on the upper 120 feet in the subsurface.

Twenty test pits will be excavated with a backhoe (12 within the burial area and 8 outside) to confirm the depth of burial and extent and determine the nature of the buried debris. Any loose medical waste encountered during performance of the test pit activities will be removed and treated with appropriate precautionary measures. The need for more extensive remedial efforts will be evaluated following the RI phase.

Groundwater. To verify the results of the previous analytical results from the 1996 through 1997 E&E sampling efforts, the four monitoring wells installed in 1996 will be sampled during two separate events, approximately six months apart.

Surface and Subsurface Soil. To determine the risk to humans and the environment posed by media to which they are commonly exposed during routine activities, 20 surface soil and a maximum of 28 subsurface soil samples will be collected at the approximate locations shown on Figure 3-1. One subsurface sample will be collected from beneath buried waste emplacements at each test pit located within the burial area. Two subsurface samples will be collected at each soil boring location outside the burial area.

Surface Water and Sediment. To determine the risk to humans and the environment posed by media to which they are commonly exposed during routine activities, a maximum of four collocated surface water/sediment pairs will be collected. One pair will be collected from each of the two drainage ditches that feed into the sinkhole immediately west of the landfill disposal area and two pairs will be collected from the sinkhole, in the approximate locations shown on Figure 3-1. Potential need for additional sampling of these media will be determined based upon evaluation of the analytical results.

Methane and Emissions Monitoring. The risk to humans and the environment posed by potential landfill methane gas emission will be evaluated. Monitoring will be conducted using polyvinyl chloride barhole probes placed between the landfill and the farmhouse and residential area located to the south and southwest of the landfill, as well as surface emissions monitoring over the landfill surface.

3.1.2.2 Landfill Area 2

Geophysical Investigation and Test Pit Excavation. A geophysical investigation of Landfill Area 2 will be conducted. This investigation will employ a combination of electrical resistivity and seismic refraction surveys to: determine the type and thickness of the landfill cover, the horizontal and vertical extent of waste burial, the location of subsurface anomalies, the nature of the bedrock surface underlying waste and overburden, and to detect voids and conduits within the bedrock that may affect contaminant transport. These surveys will focus primarily on the upper 120 feet in the subsurface.

Thirty test pits will be excavated with a backhoe (12 within the burial area, and 18 outside) to confirm the depth of burial and extent and determine the nature of the buried debris.

Groundwater. To verify the previous analytical results, the five monitoring wells surrounding Landfill Area 2 installed in 1996 will be sampled during two separate events approximately six months apart. Samples will be analyzed as described previously for Landfill Area 1.

Surface and Subsurface Soil. To determine the risk to humans and the environment posed by media to which they are commonly exposed during routine activities, 24 surface soil and a maximum of 36 subsurface soil samples will be collected at the approximate locations shown on Figure 3-2. One subsurface sample will be collected from beneath buried waste emplacements at each test pit located within the burial area. Two subsurface samples will be collected at each soil boring location outside the burial area.

Surface Water and Sediment. To determine the risk to humans and the environment posed by media to which they are commonly exposed during routine activities, a maximum of two collocated surface water/sediment pairs will be collected from the pond located near the northeast corner of the landfill, in the approximate locations shown on Figure 3-2. Potential need for additional sampling of these media will be determined based upon evaluation of the analytical results.

Methane and Emissions Monitoring. The risk to humans and the environment posed by potential landfill methane gas emission will be evaluated. Monitoring will be conducted using surface emissions monitoring over the landfill surface.

3.1.3 Selection of Sampling Locations

The locations of samples shown on Figures 3-1 and 3-2 were selected in order to maximize the number of subsurface soil samples collected from beneath buried landfill waste, in locations identified by excavation activities. Some of these locations may be revised based on current site conditions and field observations. Sample location refinements may also be made as a result of test pit excavation findings. The criteria for the present locations of the samples are as follows:

Groundwater

- Sample existing monitoring wells
- Collect samples from nearby potable wells

Monitoring wells may be necessary pending evaluation of planned groundwater flow study results.

Surface Soil

- Directly above the disposal areas
- Downslope of any buried material that has become exposed by erosion
- At or near the bottom of any sloping material covering the buried materials
- In low-lying areas of soil covering the buried materials.

Some of these locations may be revised based upon the location of areas of stained soil.

Subsurface Soil

- Circumscribe disposal areas of both landfills. Maximum of two samples per borehole: one at the highest organic vapor analyzer (OVA) reading and one for vertical delineation

- Beneath the lower buried debris boundary, and within the disposal area borders, of Landfill Areas 1 and 2. Specific sample depths will be determined in the field by evaluating test pit excavation findings.

Surface Water and Sediment

- The Landfill Area 1 collocated surface water/sediment sample pair locations will be selected in the field to maximize the likelihood of capturing information regarding potential leachate release into the two drainage ditches northwest of the landfill disposal area and into intermittent ponded storm water in the sinkhole adjacent to the landfill disposal area on the west. The distribution of the collocated sample pairs will include one each from the two drainage ditches feeding into the sinkhole and a maximum of two from the sinkhole.

- The Landfill Area 2 collocated surface water/sediment sample pair locations will be selected in the field to maximize the likelihood of capturing information regarding potential leachate release into the pond located near the northeast corner of the landfill.

3.2 Sampling and Field Procedures

The procedures for field activities will be discussed in the following sections. Chapters 5.0 and 6.0 of the SAP (Shaw, 2006a) provide detailed instructions for sample collection and data acquisition activities that will be used during the RI for Landfill Areas 1 and 2.

3.2.1 Test Pit Excavation

A total of 50 test pits will be excavated at the landfill areas to confirm the extent and depth of waste burial and nature of the waste. Twenty test pits will be excavated at Landfill Area 1, 12 within the burial area and 8 outside the burial area. At Landfill Area 2, a total of 30 test pits will be dug, 12 within the presumed burial area and 18 outside the burial area. The test pits will be dug using an excavator. A log will be completed for each test pit describing the material encountered. Each test pit will be photodocumented. Test pit location within the burial areas at both landfills will coincide with surface and subsurface soil sample locations. Figures 3-1 and 3-2 detail the proposed locations of the test pits.

3.2.2 Surface Soil Sampling Procedures

A total of 44 surface soil samples (0 to 1 foot) will be collected from the landfill areas. At Landfill Area 1, 12 samples will be collected within and 8 outside the landfill boundaries. At Landfill Area 2, a total of 12 samples will be collected within and 12 outside the landfill boundaries. Surface soil samples will be collected from the depth interval 0 to 2 feet bgs. At both landfills, the surface samples collected will be collocated with subsurface soil samples. These samples will be collected using spoons, hand augers, or other hand sampling equipment. Samples collected within the landfill boundaries will coincide with test pit locations. All sampling equipment that may come in contact with samples or sampling surfaces will be constructed of stainless steel and will be properly cleaned and decontaminated as described in Section 6.1.7 of the SAP (Shaw, 2006a) before collecting samples and between sampling locations. The VOC aliquots will be collected directly from the sampling device using Terracore™ samplers. The remaining soil will be transferred to a stainless-steel mixing bowl and homogenized. The homogenized sample will then be transferred to the appropriate sample jars. After collection, the soil samples will be labeled for proper identification (using designations listed in Table 3-1) and packed in an iced cooler pending shipment. Documentation procedures specified in Section 6.1.7 of the SAP shall be followed for the collection of all soil samples at the RAFB.

Upon receipt of the samples, the fixed-base laboratory will prepare all samples for analysis. Each sample interval will then be analyzed for the specified suite of analytes, including VOCs, SVOCs, TPH-GRO, TPH-DRO, TAL metals, pesticides, and PCBs. In addition, five of the surface soil samples collected from within and five outside the landfill boundaries will be analyzed for total organic carbon at each landfill area.

Additional information regarding collection of surface soil samples can be found in Section 6.1.1 of the SAP (Shaw, 2006a). Investigation-derived waste (IDW) generated during the soil sampling activities will be handled as described in Section 3.4 of this WP.

3.2.3 Subsurface Soil Sampling Procedures

Sampling for characterization and vertical delineation of soil contamination at the RAFB will be conducted utilizing direct-push technology. Samples collected within the landfill boundaries will coincide with test pit locations. A maximum of 44 direct-push soil borings will be drilled at the landfill areas (20 at Landfill Area 1 and 24 at Landfill Area 2). The subsurface soil borings will be drilled both inside and outside the boundaries of the disposal areas at both landfills. Equipment for obtaining the sample will be provided by a subcontractor, and a variety of equipment ensembles may be employed; however, all will share these basic elements:

- Hydraulic drive unit
- Stainless-steel sampling point
- Drive point
- Plastic sampling sleeve
- Sampling rod.

Continuous soil samples will be field screened using a calibrated photoionization detector (PID). For borings completed outside the burial areas, soil samples will be collected from the 2-foot interval displaying the highest PID reading, above the water table or bedrock. Two soil samples will be collected from borings where organic vapors are detected by the PID at concentrations greater than 10 parts per million (ppm); one from the zone with the highest PID reading and one from an interval more than 10 feet below the last reading of 10 ppm or greater. If bedrock or groundwater is encountered before readings fall below 10 ppm, then the second sample will be collected from above the water table or bedrock. If all field screening results are less than 10 ppm, then one soil sample will be collected from the 3- to 5-foot interval and from above the water table or bedrock at a depth of 10 feet bgs or less. Therefore, two soil samples will be collected from each boring from outside the landfill areas for laboratory analysis (maximum total of 16 samples from Landfill Area 1 and 24 samples from Landfill Area 2). The maximum boring depth anticipated would be approximately 30 feet bgs but would be dependent on OVA readings encountered.

One subsurface soil sample will be collected from each boring drilled within the burial area at each landfill. These samples will be collected from soil encountered beneath the buried waste. If no soil is encountered below the buried waste before bedrock is encountered, a subsurface

sample may be collected above the burial zone. Therefore, a maximum of 12 subsurface samples will be collected within the burial area of each landfill.

When the sample probe has reached the desired depth, the point will be retracted and the soil sampler driven forward to be filled. The sample device is a decontaminated stainless-steel tube with an unused inner sleeve. The sleeve will be removed from the sample tube and split open, and the sample removed.

The soil samples will be visually logged in accordance with American Society for Testing and Materials D-1452-85 using the Unified Soil Classification System and as described in Section 6.1.1 of the SAP (Shaw, 2006a). Field observations (e.g., presence of fuel product, discoloration of soil, etc.) shall be recorded in the field notes. After the sampler has been retrieved and inspected, the 2-foot sample interval will be collected for laboratory analysis. Soil collected for volatile analysis shall be collected directly from the sampling device into Terracore samplers as soon as possible after the sampler is opened to minimize volatilization. The remaining soil will be transferred to a stainless-steel mixing bowl and homogenized. The homogenized sample will then be transferred to the appropriate sample jars. The soil samples will labeled for proper identification (using designations listed in Table 3-1) and packed in an iced cooler pending transport to the site office and shipment. Documentation procedures specified in Section 6.3.3 of the SAP shall be followed for the collection of all soil samples at the RAFB. Decontamination of sampling equipment will follow Section 6.1.7 of the SAP.

Upon receipt, the fixed-base laboratory will prepare all samples for analysis. Each sample interval selected will then be analyzed for the specified suite of analytes, including VOCs, SVOCs, TPH-GRO, TPH-DRO, TAL metals, pesticides, and PCBs. In addition, 3 subsurface samples to be determined within Landfill Area 1 and 5 subsurface samples to be determined within Landfill Area 2 will be analyzed for explosives and propellants, including perchlorate by Methods 6850 and 8330. These same samples may also be analyzed for dioxins and furans if there is evidence of burning.

Direct-push sampling points will be abandoned by filling with hydrated bentonite as described in Section 5.1.2 of the SAP (Shaw, 2006a). IDW from the direct-push drilling activities will be handled as described in Section 3.4 of this WP.

3.2.4 Geotechnical Soil Samples

Selected soil samples from the vicinity of each landfill area will be analyzed for geotechnical properties. Five surface soil samples collected from within each of the landfill areas and five surface soil samples collected outside each of the landfill boundaries will be analyzed for grain size (collocated with those samples to be analyzed for total organic carbon). In addition, undisturbed subsurface soil samples (less than 10 feet bgs) from five of the soil borings (collocated with the surface geotechnical samples) outside each landfill area will be collected and analyzed for bulk soil density, total soil porosity, air-filled porosity, water-filled porosity, particle density, and fractional organic carbon. The surface and subsurface geotechnical samples collected outside the landfill boundaries will be collocated at the same borings. All geotechnical samples will be sent to Shaw's Environmental Technology Development Center for analysis.

3.2.5 Monitoring Well Sampling Procedures

Groundwater samples will be collected from the nine existing monitoring wells at Landfill Areas 1 and 2 twice. The second sample event will occur approximately six months after the first. Due to a depth to groundwater of approximately 200 feet, the monitoring well purging and sampling will be conducted using a portable bladder pump. This type of pump uses compressed air to operate a reciprocating motor piston, which pushes the groundwater to the surface. The pumps are designed such that the air does not come in contact with the groundwater. Bladder pumps are capable of lifts of up to 1,000 feet. Flow rates can be controlled so that low-flow sampling can be conducted.

Approximately 14 days prior to purging for groundwater sampling, each well will be redeveloped to remove any buildup, because the wells have not been sampled since June 1997. Purging procedures will follow those outlined in Appendix C and Section 6.1.3 of the SAP, except with the use of a bladder pump instead of a peristaltic pump. Air supply and exhaust lines for the pump will consist of polyethylene tubing. The groundwater discharge line will consist of Teflon™ or Teflon-lined polyethylene tubing. The air supply line will be connected to a portable air compressor.

Water quality parameters such as pH, temperature, conductivity, salinity, turbidity, dissolved oxygen, and oxidation-reduction potential will be measured using a YSI Model 6820 water quality meter or equivalent.

Once field parameters have stabilized, groundwater samples will be collected by direct discharge from the discharge tubing into the sample containers. Because of the depth to groundwater, the

use of bailers for collecting VOC samples is not appropriate. The sample bottles will be labeled, placed in resealable plastic bags, and stored in iced-filled coolers until shipment. Sample identification, labeling, packing, shipping, and chain of custody will follow procedures outlined in Section 6.0 of the SAP (Shaw, 2006a). Upon receipt of the samples, the fixed-base laboratory will prepare all samples for analysis. Each sample will be analyzed for the specified suite of analytes, including VOCs, SVOCs, TPH-GRO, TPH-DRO, TAL metals (total and dissolved), pesticides, PCBs, anions, total dissolved solids, total suspended solids, and alkalinity.

All sampling and purging equipment will be decontaminated before use and after each successive use in accordance with decontamination procedures outlined in Chapter 6.0 of the SAP.

3.2.6 Surface Water and Sediment Pair Sampling Procedures

A maximum total of six collocated surface water/sediment sample pairs will be collected from the landfill areas. At Landfill Area 1, one collocated sample pair will be collected from each of the two drainage ditches that drain into the sinkhole adjacent to the landfill disposal area on the west. A maximum of two collocated sample pairs will be collected from the sinkhole. Water is present in both the drainage ditches and sinkhole typically only after a large rain event. If surface water is not present, a soil sample may be collected from each proposed location. At Landfill Area 2, a maximum of two collocated sample pairs will be collected from the pond near the northeast corner of the landfill. Surface water samples will be collected using a Pyrex® ladle, Teflon dipper, glass beaker, or Wheaton® or similar subsurface sampling apparatus. All sample collection apparatuses will be properly cleaned and decontaminated as described in Section 6.1.4 of the SAP (Shaw, 2006a) before and between sample collections.

Sediment samples will be collected directly beneath the location selected for the surface water samples, with sample collection devices such an Eckman dredge, sludge sampler, or bucket auger. In the case of the drainage ditches at Landfill Area 1, where surface water is absent, samples will be collected with spoons, split spoons, or a bucket auger. Approximate sample locations are illustrated on Figures 3-1 and 3-2; the sample technician in the field will assess the area and use his judgment in selecting the most representative locations.

Upon receipt of the samples, the fixed-base laboratory will prepare all samples for analysis. Each sample will be analyzed for the specified suite of analytes, including VOCs, SVOCs, TPH-GRO, TPH-DRO, TAL metals, pesticides, and PCBs.

All samples will be labeled for proper identification (using designations listed in Table 3-1), and packed in an iced cooler pending shipment. Documentation procedures specified in Section 6.1.4 of the SAP shall be followed for the collection of all surface water samples at the RAFB.

Additional information regarding collection of surface water samples can be found in Section 6.1.4 of the SAP; additional information regarding collection of sediment samples can be found in Section 6.1.2 of the SAP (Shaw, 2006a).

3.2.7 Groundwater Flow Studies

Groundwater flow studies will include use of a colloidal boroscope flowmeter and downhole camera to document flow direction and velocity in each existing monitoring well. Borehole alignment will also be measured at each well to determine the degree of deviation from vertical. Additionally, follow-up dye injections into the subsurface of Landfill Areas 1 and 2 may be employed if groundwater flow study results leave significant uncertainty in groundwater flow interpretation. Upon obtaining results from these studies, the potential need for additional wells at each landfill can be evaluated.

3.2.8 Landfill Gas Monitoring

Monitoring for the presence of methane at each landfill will be conducted due to unknown past disposal practices. Methane gas is common in landfills and can create an explosion hazard if levels are excessive. If methane is present, the survey will indicate if gas is escaping from the landfills and if there is a potential for migration outside the landfill areas.

Surface Emissions Monitoring. Surface emissions monitoring will be conducted for Landfill Areas 1 and 2 to assess whether landfill gas (LFG) is migrating through the cover soils. Satisfactory SEM results with no gas abatement system in place will indicate that no migration control measures will be required at the landfills. Testing will be conducted in accordance with applicable methods presented in the new source performance Standards regulations and conforming to Title 40 Code of Federal Regulations (CFR), part 60.755, b-d. A portable gas monitor such as a PhotoVac MicroFID or equivalent will be used. Shaw will then perform background monitoring to conform to 40 CFR, part 60, Appendix A, Method 21.

Concentrations of methane gas will be recorded outside the landfill boundaries, upwind and downwind, to measure background levels. The surface area of landfills 1 and 2 will be measured for methane by completing a serpentine pattern across the surface of the two landfills, with each traverse spaced approximately 50 feet apart. During the traverse, the monitoring probe of the FID

will be positioned approximately 2 to 4 inches above the ground surface. All measurements will be recorded with a date, time, and location. Any location with gas concentrations exceeding the 500-parts-per million threshold value will be marked in the field with a unique identifier.

Barhole Probe Monitoring. Barhole probe monitoring will be conducted at landfill Area 1 only in order to assess the potential for off-site migration of LFG to nearby residential areas to the south and southwest. An estimated five barhole probes will be installed along the southwest side of landfill Area 1 as shown on Figure 3-1. The barhole probing will be conducted by driving an approximate 0.5-inch-diameter PVC screen into the ground to a total depth ranging from 1 to 3 feet bgs. A hand auger may be used if the lithology does not allow the probes to be driven. Following completion, the probe will be removed from the hole and a sampling tube will be inserted to the bottom. The sampling tube will be connected directly to a GEM 500 CGI, capable of measuring the major components of LFG (methane, oxygen, carbon dioxide, and nitrogen). The measurements and locations will be recorded at least twice during the RI field work.

3.2.9 Quality Assurance/Quality Control Sampling

To ensure the reliability of field sampling procedures and materials, field QA/QC samples will be collected or prepared as appropriate for each medium sampled, each sample shipment, and/or each sampling event. The field activities will be considered one event unless the field personnel leave the site for more than 72 hours during the course of the investigation. All water used during field sampling as analyte free will be deionized, organic-free water prepared to EPA standards. Chapter 6.0 of the SAP (Shaw, 2006a) provides specified information regarding QA/QC samples and describes how to identify and document QA/QC samples.

3.2.10 Decontamination Procedures

Sampling Equipment. Decontamination of data acquisition and sampling equipment will be performed in accordance with Chapter 6.0 of the SAP (Shaw, 2006a) to maintain the integrity of the soil and groundwater samples collected during the field investigation.

Nonsampling Equipment. All equipment that may contact the interior of a borehole or that may contact other equipment entering the hole shall be thoroughly cleaned using steam or high-pressure hot water. Decontamination will be performed prior to setting up on the first sampling location, between each sampling location, following sampling, and at the last sampling location. No tools or equipment should contact the ground or become contaminated after cleaning until used in sampling. If contamination occurs, contaminated items shall again be cleaned before use

in the manner previously specified. At the sampling location, cleaned equipment shall be kept off the ground by storing on cleaned metal racks (not wooden pallets) or on polyethylene-covered pallets.

3.2.11 Sample Custody and Tracking Procedures

Sample custody is a vital aspect of an environmental investigation because it will ensure integrity of samples and eventual defensibility of the data. Proper sample custody procedures will result in a record of sample stewardship from collection until the analyses have been performed. This means that all steps of the investigation will be repeatable and that all information used to draw conclusions and make recommendations will be as accurate as possible. All sample custody and tracking procedures, including laboratory notification, field custody procedures, identification, and shipping will be performed as specified in Section 6.2 of the SAP (Shaw, 2006a).

3.2.12 Documentation

All field activities shall be documented to maintain a record of the progress of the fieldwork and to allow the reconstruction of events that occur during the RI of Landfill Areas 1 and 2. Field documentation forms to be used during the RI of Landfill Areas 1 and 2 include field activity daily logs, sample collection logs, soil classification logs, groundwater sample collection logs, and analysis request/chain-of-custody records. The procedures for identifying and documenting samples collected during the RI at Landfill Areas 1 and 2 are presented in Section 6.3 of the SAP (Shaw, 2006a).

Shaw recognizes two types of work plan deviations: the nonconformance and the variance. A nonconformance is defined as an unplanned deviation that occurs during task implementation, but is not identified until after task completion. As a result of this event sequence, a nonconformance cannot usually be corrected.

A variance is similar to a nonconformance, with the exception that the variance is identified prior to task implementation. In the case of a variance, alternative techniques, modified methods, or a task change can be considered. Documentation via completion of specific forms will be required in the case of both nonconformances and variances.

A form allowing for the detailed documentation of landfill contents during test pit activities has been developed. This form will permit documentation of any evidence of burning, ash presence, evidence of drums or waste containers, potential asbestos presence, staining, odors, waste quantity and locations, and other landfill contents.

Examples of all documentation forms discussed in this section are provided in Appendix A.

3.2.13 Field Instrument Calibration

Field testing and monitoring equipment will be inspected and calibrated before use. Testing and monitoring equipment includes hand-held organic vapor monitors (e.g., OVA) used for health and safety air monitoring and for screening soil vapors, combination pH/temperature/conductivity, oxidation-reduction potential, dissolved oxygen, salinity, and turbidity meters. Calibration standards for these instruments will be kept on site and in good condition. Each day an instrument is used, its calibration will be compared against one of these certified standards. Additional information regarding instrument calibration procedures and records is presented in Section 6.4 of the SAP (Shaw, 2006a).

3.3 Sample Analysis

Summaries of the samples to be submitted for laboratory analysis and analytical methods are presented in Tables 3-1 and 3-2. Off-site analyses will be performed by Accutest using EPA methods and will meet the QA/QC requirements described in the referenced SW846 methods and the SAP (Shaw, 2006a).

Analytical samples collected for off-site analysis during this investigation will be sent to:

Accutest Laboratories, Inc.
4405 Vineland Road, C-15
Orlando, Florida 32811
Contact: Sue Bell
Phone: (407) 425-6700.

3.4 Investigation-Derived Waste

Investigations generate development water, purge water, drill cuttings, decontamination liquids, and personal protective equipment. IDW will be characterized as hazardous or nonhazardous and will be disposed of accordingly. Materials deemed hazardous will be disposed within 90 days, as specified in the SAP (Shaw, 2006a).

The purpose of this section of the WP is to provide a plan that will allow a consistent format for determining the disposition of wastes generated during investigation activities at the RAFB. Development of this section was guided by the EPA document *Management of Investigation-Derived Wastes During Site Inspections*, EPA/540/G-91-009 (EPA, 1991a).

IDW such as soil and decontamination fluids will be collected separately in 55-gallon drums. Each container will be marked in English and Spanish showing the date of collection, area of collection, the nature of the waste (e.g., solid or liquid, etc.), and the name and telephone number of the contact person. The drums will be inventoried on an IDW/drum inventory log. The drums will not contain mixtures of soil or water from different well or site locations. All drums will be sealed and the containers covered to prevent leakage of the contents or introduction of contamination from external sources. Drums will be placed on pallets to facilitate handling. Analysis will be performed on composite samples of the solid IDW for native concentrations as needed. Decontamination fluid IDW will be characterized as needed. The following sections describe in more detail the general sampling and analysis approach for solid and liquid IDW.

3.4.1 Technical Rationale

The Shaw team members for the RAFB effort will consult with the staff regulatory specialist to review the existing data on a waste stream. From the review, the regulatory specialist will determine the following:

- Are the collected data sufficient to characterize the waste as hazardous or nonhazardous?
- Can a hazardous waste profile and hazardous waste manifest be prepared if the waste is hazardous?
- What are the disposal options for the waste for classification as either hazardous or nonhazardous?

After these questions have been addressed, the regulatory specialist will prepare a memorandum for the project manager (PM) summarizing the results of his evaluation of the waste stream data. He will also prepare a waste profile and manifest if the waste is determined to be hazardous. The PM will evaluate the recommended disposal options and prepare bid packages to solicit proposals from transport/ disposal subcontractors to handle and dispose of the waste. The PM will next compile an approval package consisting of the regulatory specialist's memorandum, profile and manifest (if needed), supporting analytical data, subcontractor cost proposal results, and copies of waste handling permits and licenses of the recommended subcontractors. The PM will then compose a cover letter for the package explaining where the waste was produced, the quantity, the results of analysis, the determination of hazard status, and the recommended disposal option. This package will then be sent to the USACE PM for review and approval. A USACE representative will be responsible for signing any necessary waste profiles and

manifests. When approval is received, Shaw will contract the selected subcontractors to arrange for pickup and off-site disposal. If the waste is not hazardous, the disposal options are described below.

The following sections discuss the specific IDW characterization steps and disposal options available for use.

3.4.2 Solid Investigation-Derived Waste

The first step in determining disposal options for IDW is to determine if the waste is a hazardous waste as defined in Title 40 Code of Federal Regulations (CFR) Part 261, Resource Conservation and Recovery Act (RCRA). This determination can be made either by knowledge of the generating process or by comparing analytical results to the levels that would be required from the toxicity characteristics leaching procedure (TCLP) test. If analytical results are less than 20 times the action levels required from the TCLP in 40 CFR 261.24, then waste is generally considered to be nonhazardous. On the other hand, if analytical results are greater than 20 times the action levels required from the TCLP, the waste may be considered hazardous. However, the regulatory specialist or USACE may elect to run the TCLP tests to make the determination with certainty. If the IDW is hazardous under RCRA, it must be disposed of at a Subtitle C RCRA-permitted treatment, storage, and disposal facility. Shaw will contract the facility to provide disposal. Shaw will obtain manifests for signature by USACE representatives and oversee pickup of the containers by a qualified transporter. USACE will review the manifests within three days of receipt. The USACE chemist will be contacted for further information as needed. Shaw will also prepare land disposal restriction notification as applicable.

If an IDW is not hazardous under RCRA or concentrations of analytes are less than 20 times the TCLP limits, it may be possible to dispose of it in either a Subtitle D landfill or municipal landfill. Upon concurrence of the regulatory specialist, the soil IDW may be spread on the ground.

3.4.3 Liquid Investigation-Derived Waste

Liquid IDW from the RI of Landfill Areas 1 and 2 will consist of either groundwater from well development/purging or equipment decontamination fluids. Equipment decontamination fluids will be collected and drummed and a representative composite sample collected from the containers for characterization and analysis. Groundwater from well development/purging activities will be containerized in segregated drums and labeled with the source area (Landfill Areas 1 or 2) and the well identity. Assuming that the purged groundwater has similar

concentration of contaminants as the collected field samples, no additional sampling will be required for characterization. The results of the field samples will be evaluated upon receipt to determine the disposal options for the associated water IDW. One of the following options will be selected based on the field sample results:

- Where analytical results indicate trace levels (less than the reporting limit) or no contamination present for the site contaminants of concern, the results will be forwarded to the USACE PM for review, with a recommendation that the corresponding waste be poured onto the ground as nonhazardous material.

- Where analytical results indicate other contaminants are especially high in concentration, the data will be forwarded to the Shaw regulatory specialist and a determination made on whether or not the IDW is hazardous. The USACE PM will then be contacted for concurrence. The procedures for disposal as hazardous waste previously described will be followed.

3.4.4 Other Investigation-Derived Waste

Other IDW generated during the RI of Landfill Areas 1 and 2 may include such items as personal protective equipment, decontamination pad plastic and sheeting, and consumable supplies. These materials will be considered either hazardous or nonhazardous according to the characteristic of the other forms of waste generated during sampling activities. If the soil and liquid IDW is considered nonhazardous, then the other waste generated during that same sampling activity will also be nonhazardous. If soil and liquid IDW is found to be hazardous, then other waste generated will be hazardous.

4.0 Baseline Human Health Risk Assessment

4.1 Introduction

The BHHRA WP was prepared to describe the protocol for evaluating human health risks associated with exposure to soil and groundwater associated with and underlying Landfill Area 1 and Landfill Area 2 at the RAFB. The methodologies and assumptions described by this protocol are consistent with current EPA guidance as referenced in this chapter.

4.1.1 Background Information

The RAFB is located on the extreme northwestern tip of Puerto Rico, near the city of Aguadilla (Figure 1-1). The former Base, which occupies approximately 4,357 acres, was acquired by the U.S. Government between 1939 and 1963 and was fully operational until its deactivation in 1973. The Base property is currently occupied by the Puerto Rico Port Authority, Puerto Rico National Guard, U.S. Customs, U.S. Coast Guard, educational facilities, several privately owned businesses, and residential property. Portions of the former Base also are leased to local farmers (E&E, 2001).

4.1.2 Site Description

Landfill Area 1. This former disposal area covers approximately 6.2 acres. Topographic relief in the area of Landfill Area 1 is approximately 70 feet and slopes toward a sinkhole immediately west of the disposal area. The sinkhole is approximately 35 feet deep and 0.8 acre in size.

A hill of approximately 1 acre is located immediately north of the sinkhole. The time period and nature of disposals at this site could not be determined from existing records. However, a 1966 map of the Base refers to Landfill Area 1 as a “sanitary fill” area. An aerial photograph indicates that disposals were occurring in 1970, but this is the only information on disposals discovered to date.

Some of the landfilled material has become exposed at the surface due to erosion, especially along the western edge of the disposal area. Construction debris and scrap metal are present on the ground surface and are believed to be present below grade. There has also been some public dumping of refuse south and east of the landfill area. Some medical waste of unknown origin, including intravenous bags and tubing, latex gloves, and syringes, has been observed in the sinkhole. The medical waste appears to have been placed in fabric bags prior to being disposed of in the landfill. This medical waste is believed to have been transported into the sinkhole

during storms (E&E, 2001). A more complete description of Landfill Area 1 is provided in Section 2.2. Landfill Area 1 is currently being used as pasture for cattle.

Landfill Area 2. Landfill Area 2 (Figure 2-3) is within a flat, grass-covered field. The area used for disposal is believed to be approximately 23 acres and is currently used as part of a larger area by a tenant for grazing and crop growing. Although Landfill Area 2 is reported to have received municipal, household garbage from a former adjacent Air Force housing development, no records of disposal activities at this site have been located to date. Several old building foundations on the Landfill 2 property appear to have been built when the Base was operating (E&E, 2001). An irrigation pond was recently constructed northeast of the former disposal area by USACE and altered by the tenant farmer to use for drinking water for cattle. This pond is supplied with off-site water. A broad, shallow sinkhole is located about 200 feet north of the burial area. Only the northernmost portion of the Landfill 2 area drains into the sinkhole; the reminder of Landfill Area 2 is sloped toward the south. A more complete description of Landfill Area 2 is provided in Section 2.2. Landfill Area 2 is currently being used to grow crops that are intended for human consumption.

4.1.3 Organization of the Baseline Human Health Risk Assessment

The BHHRA will present the methods used, results generated, and the interpretation of these results. The report will be organized as follows:

- Data Evaluation. Identifies data sources, evaluates data quality, identifies chemicals of potential concern (COPC), and provides a background screening.

- Exposure Assessment. Presents a conceptual site exposure model (CSEM), including contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; describes exposure-point concentrations (EPC); and presents methods for calculating chemical intake and contact rates.

- Toxicity Assessment. Describes the potential for cancer and/or noncancer human health effects, provides an estimate of the quantitative relationship between the magnitude of dose or contact rate and the probability and/or severity of adverse effects, identifies the toxicity values that are used in the BHHRA, and describes the development of dermal toxicity values.

- Risk Characterization. Combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor in each area of concern.

- Uncertainties Analysis. Identifies uncertainties in all phases of the BHHRA and discusses their individual effects on the risk assessment results, emphasizing those

items that are most likely to have the greatest effect on risk estimates and/or site management decisions.

- Summary/Conclusions. Provides a brief summary of the entire BHHRA, including quantitative results, uncertainties, and pertinent site information. Summary and discussion is focused on those results and issues that are most likely to directly affect site management decisions.

4.2 Data Evaluation

Data evaluation consists of a description of the appropriate data sources for each environmental medium associated with the BHHRA, a discussion of data quality, a description of the methodology for the identification of COPCs, and a presentation of the COPCs for Landfill Area 1 and Landfill Area 2 environmental media.

4.2.1 Data Sources

Data used in the BHHRA will be the analytical results of soil and groundwater samples collected as described in Section 3.2. All of the groundwater and surface soil samples, and a subset of the subsurface soil samples, will be used in the BHHRA. Specifically, it is anticipated that the following samples will be included:

- Landfill Area 1 – Four monitoring well groundwater samples and 20 surface soil samples
- Landfill Area 2 – Five monitoring well groundwater samples, 24 surface soil samples, and up to 48 subsurface soil samples.

Subsurface soil samples will be collected from borings at the two landfill areas. The borings will be analyzed in the field using a PID, based on continuous 2-foot depth intervals. As described in Section 3.2.2, the depth interval selected for laboratory analysis from each boring will be the one with the highest PID reading. At Landfill Area 2, the BHHRA will include laboratory analytical results of subsurface soil samples collected within a depth range of 1 to 10 feet bgs. If both samples from a given boring are within the 1- to 10-foot depth range, then both will be evaluated as subsurface soil in the BHHRA. Borings that do not have soil collected within this depth range will not be included in the BHHRA. Exposure to soils from intervals deeper than 10 feet bgs are not regarded as plausible at Landfill Area 2.

Because disturbance of the subsurface soil is not plausible at Landfill Area 1 due to stability issues (Section 4.3.1.5.1), only surface soil samples are planned to be quantitatively evaluated in the BHHRA for Landfill Area 1. If any of the subsurface soil samples at Landfill Area 1 are

collected from the near-surface interval of 1 to 3 feet bgs, analytical results of these samples will be evaluated for potential exposure via indirect pathways (e.g.., via ingestion of beef [refer to Section 4.3.1.5.1]). This evaluation would be included in the text of the BHHRA. Note that given the opportunity for volatilization at the near-surface depth range of 1 to 3 feet bgs, it is anticipated that none of the highest PID readings will result from this shallow depth range at Landfill Area 1.

4.2.2 Evaluation of Data Quality

The quality of the analytical data is evaluated to select data for inclusion in the BHHRA. Data quality is expressed by the assignment of qualifier codes during the analytical laboratory QC process or during data validation that reflect the level of confidence in the data. The following are some of the more common qualifiers and their meanings (EPA, 1989a):

U - Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.

J - Value is estimated, probably below the contract-required quantitation limit.

N - The analysis indicates an analyte for which there is presumptive evidence to make a tentative identification.

NJ- The analysis indicates a “tentatively identified analyte,” and the reported value represents its approximate concentration.

UJ- The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

R - QC indicates that the data are unusable (chemical may or may not be present).

B - The concentration in the sample is not sufficiently higher than concentration in the blank, using the 5-times, 10-times (5x, 10x) rule: A chemical is considered a nondetect unless its concentration exceeds five times the blank concentration. For common laboratory contaminants (acetone, 2-butanone [methyl ethyl ketone], methylene chloride, toluene, and the phthalate esters), the sample concentration must exceed 10 times the blank concentration to be considered a detection.

Data qualified “J,” “N,” and “NJ” will be used in the BHHRA; “R” and “B”-qualified data will not. The handling of “U”-qualified data (nondetects) in the BHHRA is described in Section 4.3.3.1. The use of data with other, less common qualifiers will be evaluated on a case-by-case basis. Generally, data for which the identity of the chemical is unclear are not used in the

BHHRA. When confidence is reasonably high that the chemical is present, but the actual concentration is somewhat in question, the data generally are used in the BHHRA. The results of field duplicates will be averaged for that sample, and these average values will be used as the representative values in that sample for the respective analytes.

Some chemicals may be analyzed under two different analytical programs. For example, naphthalene is analyzed in groundwater by EPA Method 8260B for VOCs and EPA Method 8270C for SVOCs. Risks associated with the reported values from both analyses, if detected, will be provided in the risk characterization (Section 4.5) and discussed as appropriate in the uncertainties analysis (Section 4.6) together with potential issues such as the relative sensitivities (i.e., differences in respective reporting limits) of the methods.

4.2.3 Identification of Chemicals of Potential Concern

The purpose of identifying COPCs is to focus the analysis on a set of chemicals that may be pertinent to human health risks. The COPC process includes a screening protocol that considers, in order, status as essential macronutrients, risk-based screening, and frequency of detection. A chemical that passes each of the following screening criteria is retained as a COPC.

4.2.3.1 Exclusion of Essential Macronutients

Elements that are identified as essential macronutients (calcium, sodium, potassium, and magnesium) are excluded from consideration in the BHHRA. The nutritional element iron is carried through the COPC selection process; however, due to concerns with the oral reference dose (RfD) for iron, this chemical is evaluated qualitatively if it is chosen as a COPC, not quantitatively. If iron is chosen as a COPC, further discussion regarding the concern over the RfD will be included in the BHHRA.

4.2.3.2 Regional Screening Levels

This step of the human health risk assessment screening consists of comparing the maximum detected concentration (MDC) with screening criteria derived from Oak Ridge National Laboratory-EPA regional screening levels (RSL) for all site samples (Oak Ridge National Laboratory-EPA, 2009).

RSLs are screening levels that reflect an incremental lifetime cancer risk (ILCR) of 1E-6 and a hazard index (HI) of 1.0. For the Landfill Area 1 and Landfill Area 2 sites, the RSLs will be adjusted as necessary to reflect an HI of 0.1 for noncancer effects, providing additional protection for simultaneous exposure to multiple chemicals. Chemicals whose MDCs are less

than their RSLs are not considered further in the risk assessment because it is very unlikely that they would contribute significant risk. If no chemical within a medium exceeds its RSL, then that medium and its exposure pathways are eliminated from the risk assessment process. If the MDC exceeds the RSL, the chemical is selected as a COPC for that medium. Chemical concentrations in surface soil and subsurface soil are compared with “residential soil” RSLs.

4.2.3.3 Frequency of Detection

When confidence is high that a given chemical is present, the data generally are used in the BHHRA. For most chemicals, their detection is presumptive evidence of their presence. As suggested by EPA (1989a), chemicals that are reported infrequently may be artifacts in the data that do not reflect the actual presence of the chemical in question. For the Landfill Areas 1 and 2 BHHRA, chemicals that are reported only at low concentrations in less than 5 percent of the samples from a given medium will be excluded from further consideration, unless their presence is expected based on historical information about the site. Chemicals detected infrequently at high concentrations may identify the existence of contaminant plumes or limited “hot spots” and are retained as COPCs.

4.2.4 Chemicals Not Detected

It is not uncommon to have several chemicals in a given medium for which all analytical results are reported as "not detected.” In the case that their detection limits are below their risk-based screening levels (RBSL), it is unlikely these chemicals, even if present at their detection limits, would contribute significantly to site risk. It is possible, however, that undetected chemicals with detection limits greater than their RBSLs could be present at concentrations associated with significant risk. Such chemicals will be addressed qualitatively in the screening-level risk assessment and during the BHHRA, if it is possible that their presence could be associated with unacceptable risks.

4.2.5 Data Evaluation Summary

Separate tables will be prepared for Landfill Area 1 and Landfill Area 2 with the following information for each detected chemical:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of detection limits
- Arithmetic mean of site concentrations
- 95th percent upper confidence limit on the arithmetic mean (UCL)

- RBSL
- Upper tolerance limit (UTL) of the background (for soil)
- Selection/exclusion of chemical as a COPC.

As discussed in Section 4.2.3, the chemicals identified as COPCs will be carried forward in the exposure assessment (Section 4.3).

4.3 Exposure Assessment

Exposure is the contact by a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPCs found at or migrating from a site (EPA, 1989a). The following steps are included in an exposure assessment:

- Characterize the physical setting.
- Identify the contaminant sources, release mechanisms, and migration pathways.
- Identify the potentially exposed receptors.
- Identify the potential exposure pathways.
- Estimate EPCs.
- Estimate chemical intakes or contact rates.

The BHHRA described in this WP will characterize exposure to COPCs in soil and groundwater associated with Landfill Areas 1 and 2. Estimates of potential exposure will be used in the BHHRA risk characterizations to quantify risks.

4.3.1 Conceptual Site Exposure Model

The CSEM provides the basis for identifying and evaluating the potential risks to human health in the baseline risk assessment. The CSEM includes the receptors appropriate to all plausible exposure scenarios. The CSEM presents all possible pathways by which a potential receptor may be exposed, including all sources, release and transport pathways, and exposure routes. It facilitates consistent and comprehensive evaluation of risk to human health and helps to prevent potential pathways from being overlooked. The elements of a CSEM include the following:

- Physical setting
- Source of contamination potentially released at site
- Source media (i.e., soil)
- Contaminant release mechanisms
- Contaminant transport pathways
- Transport (secondary, tertiary) media
- Exposure media (e.g., surface soil, dust, ingested beef)
- Receptors
- Routes of exposure (ingestion, inhalation, dermal contact).

Contaminant release mechanisms and transport pathways that result in the transfer of contaminants across media are not relevant for direct receptor contact with a contaminated source medium (e.g., incidental ingestion of soil). The receptors and pathways shown on Figures 4-1 and 4-2 reflect exposure scenarios for Landfill Areas 1 and 2, respectively, developed from information regarding site background and history, topography, climate, and demographics.

4.3.1.1 Physical Setting

The United States Government acquired the RAFB property between 1939 and 1963. The site was operated as an Air Force Base until deactivation in 1973. During this period, actual landfilling activities appear to have been conducted across an area of approximately 6 acres. A 1970 aerial photograph shows the landfill in operation, but file information detailing exact period or duration of landfill activities is not available (E&E, 2001). The types of materials disposed in the landfills are incompletely known. It is unknown whether trenches were used at the landfills.

Landfill Area 1. Landfill Area 1 is a 6.2-acre, predominantly open grass area, with a patch of sparse shrub/scrub vegetation on the south-central portion of the landfill and a few deciduous trees on the southeast side (IT, 2000). The Landfill Area 1 site consists largely of the landfill proper. Although the exact boundaries of the landfill proper are not known, there appears to be a narrow perimeter of land outside the landfill proper. The entire area is fenced with barbed wire and currently used as a pasture for cattle. The landfill slopes from east to west, with a large drainage ditch that terminates in a large sinkhole on the western side. The sinkhole has an area of approximately 0.8 acre, is approximately 30 feet deep, and is fenced with barbed wire to exclude the cattle. The entire surface of Landfill Area 1 appears to be unstable, rendering it unlikely to be tilled and used for crop production or developed for any other purpose. Exposed medical waste was observed in the wall of the drainage ditch, in the wall and on the floor of the sinkhole, and in the paths worn in the soil by the cattle, particularly on the western side. This observation suggests that the soil cover may be thinner on the western side of the landfill. It is also possible that the sinkhole and the drainage ditch may be expanding over time as a function of the karst setting, leading to medical waste exposure within the previously buried confines of the landfill.

The drainage ditch, situated along the northwest side of the landfill, is entirely canopied by deciduous trees and thick underbrush. The ditch is approximately 4 to 6 feet wide at the base, and the walls are approximately 10 to 15 feet in height. The bed and walls of the ditch show evidence of large volumes of water rushing through the ditch. Presumably, heavy rains create

surges of overland runoff, which is channeled through the ditch and into the sinkhole. The ditch appears to be eroding into the sinkhole. It appears to contain water only during storm events. A residential area is located across the road from the landfill. Industrial and commercial buildings are located next to and across from a frontage road on the eastern side of the landfill.

Landfill Area 2. The Landfill Area 2 site includes approximately 23 acres that are believed to have been used for disposal. It is within a larger, fenced agricultural field surrounded by other agricultural fields, cow pastures, and abandoned Base housing (IT, 2000). The exact border of the landfill proper is unknown, but the Landfill Area 2 site includes a substantial perimeter outside of the landfill proper. Only the northwest corner of the site is not presently tilled or planted with commercial/subsistence crops. This corner is vegetated with tall grasses. The landfill terrain can be described as flat to very gently rolling hills, with the highest point in the northeastern corner. Low points of the landfill are along the western boundary, the southeastern corner, and the north-central boundary.

A sinkhole appears to be forming to the north of the agricultural field. It does not include areas thought to contain landfilled material and may include part of the landfill, though this could not be verified based on field observations. Currently, the sinkhole is approximately 40 feet in diameter at ground level, slopes to approximately 20 feet in diameter at the bottom, and is approximately 5 to 6 feet deep. A drainage ditch runs along the western fence line of the site. The ditch begins abruptly and does not appear to lead to any surface water body, but rather gently spreads out until it blends in with the ground surface. Although this ditch appears to be located within the landfill boundary, no waste was observed in the ditch. There is no evidence of aquatic biota, and based on field observations, the ditch is presumed to contain water only during storm events. It could not be visually determined how much of the landfill is within the tilled area and how much is within the surrounding cow pasture.

A pond is located to the northeast of the historical landfill boundary. It is man-made and is surrounded by a barbed wire fence. Local field workers indicate that the pond is filled with water from a municipal reservoir. The water is used to irrigate crops via gravity feed and provide water for cattle. Because the pond is located at the highest point of the area, is fed from an off-site source, and is not located in an area identified as containing disposed material, it is not expected that potential contaminants from the landfill would migrate via groundwater or surface runoff into the pond.

The area surrounding Landfill Area 2 is agricultural. A few residences are located in this area.

4.3.1.2 Source of Contamination Potentially Released at Site

The source of the contamination potentially released at the landfills is the waste materials dumped or buried at the site.

4.3.1.3 Media of Interest

Potentially contaminated source media are probably limited to surface and subsurface soil. The water table is located more than 200 feet bgs; therefore, it is unlikely that waste would have been disposed directly into groundwater. Potential exposure media relevant to the RAFB landfills are limited to surface and subsurface soil and ambient air. Although groundwater may be contaminated by leaching and, possibly, preferential flow pathways associated with the karst geology, exposure to groundwater is probably implausible because 1) other sources of potable water in the region are readily available from PRASA, and 2) the deep water table makes installation of a private well expensive. Consistent with these observations, groundwater in the area is not used as a source of potable water. However, groundwater is being sampled as part of this investigation, so groundwater will be evaluated as a potential source of potable water for future off-site residential use in this BHHRA. The groundwater evaluation in the BHHRA will clearly state that exposure to groundwater is not a current exposure pathway and that use of groundwater is highly unlikely to occur in the foreseeable future.

As mentioned, the water table is at a depth of over 200 feet and the land elevation is over 200 feet above msl. Accordingly, the water table elevation is within about 5 feet of sea level. Therefore, groundwater does not discharge to on-site surface water bodies or to any other freshwater features in the vicinity. Based on the analytical results of previous sampling efforts, surface water and sediment in the ditches does not appear to be impacted by site disposal activities (E&E, 2001). Also, surface water appears to be present only during storm events. Therefore, it is unlikely that human receptors would be repeatedly and predictably exposed to either surface water or sediment. As previously noted, surface water and sediment in the irrigation/cattle watering pond associated with Landfill Area 2 would not reflect contamination from the landfill, as this pond is supplied by an off-site source, is of fairly recent construction, is within a topographic high, and is outside of the area which contains disposed material (E&E, 2001). Therefore, surface water and sediment are not sampled or evaluated in the BHHRA.

4.3.1.4 Release Mechanisms and Transport Pathways

Potential contaminant release mechanisms and transport pathways relevant to risk assessment of the landfills include the potential migration of contaminated leachate through soil to groundwater

(potentially a potable water source), release of soil dust, and volatilization of VOCs from soil into the air. In addition, vegetation growing on contaminated soil may accumulate contaminants that are ingested by livestock, that provide food for humans, or that are ingested directly by humans.

4.3.1.5 Identification of Receptors and Exposure Pathways

A few different types of receptors may be exposed to surface and subsurface soil at the RAFB landfills under both current and future site-use assumptions. These are identified in the subsections that follow. Refer to Section 4.3.2 for further description and assumptions associated with these receptors.

4.3.1.5.1 Landfill Area 1

Current Site-Use Scenarios. Landfill Area 1 is currently used to pasture cattle. The instability of the terrain renders it practically unsuitable for any other use. Although Landfill Area 1 is fenced, the barbed wire fencing used to control cattle would not prevent trespassers from visiting the site. Plausible receptors include an off-site farmer who is a consumer of animal agriculture products (off-site consumer), a young child recreational receptor, and a youthful trespasser (direct exposure to soil). Groundwater is not currently used in the vicinity of the site.

- Off-Site Consumer. Either dairy or beef cattle may be pastured on Landfill Area 1. However, Landfill Area 1 is relatively remote and is located a considerable distance from the nearest farmstead that might operate a dairy. While it is unlikely that currently lactating cattle would be pastured on Landfill Area 1 because of the labor involved in moving them to and from a milking facility twice daily, the possibility cannot be ruled out. Therefore, it is assumed that beef cattle and lactating dairy cattle are pastured on the landfill.

  Cattle may be exposed to contaminants in surface soil at Landfill Area 1 indirectly by grazing pasture grasses that accumulate contaminants from soil, and directly by incidental ingestion of soil while grazing. Humans may be exposed to soil directly while moving cattle to and from the pasture, and indirectly by consumption of milk or beef. Direct exposure during the movement of cattle is expected to be short in duration and infrequent because of the remote location of the pasture relative to nearby farmsteads. Therefore, it is assumed that direct exposure to the farmer is insignificant compared with the potential for indirect exposure via consumption of animal products, and direct exposure is not evaluated for the off-site consumer.

  Indirect exposure of the off-site consumer could involve consumption of milk and beef. Therefore, it is assumed that the off-site consumer is indirectly exposed to soil at Landfill Area 1 by ingestion of beef and milk.

- Youthful Trespasser. A youthful trespasser may readily gain access to Landfill Area 1 for the purpose of hiking or playing, thereby becoming directly exposed to surface soil. This trespasser is not assumed to be restricted by fences. Potentially complete direct exposure routes include incidental ingestion and dermal contact with surface soil, and inhalation of dust and volatiles.

- Young Child Recreational Receptor. A young child is assumed to visit Landfill 1 as a play area. The exposure routes are the same as for the youthful trespasser. The exposure parameters for this young child are the same as for resident child exposure (see Section 4.3.1.5.2) to soil except for exposure frequency, which is the same as the youthful trespasser scenario.

Future Site Use. There are no plans to develop Landfill Area 1 for any future use. As previously noted, the presence of a sinkhole and the unstable nature of the terrain render the site unsuitable for future development. Therefore, it is assumed that future site use will be the same as current site use. The receptor scenarios developed for current site use also apply to future site use.

Although the site is unsuitable for development, it is possible that areas downgradient of the site could be used for future development, including residential development. The water table at Landfill Area 1 is at a depth of over 200 feet, and municipal water is readily available from PRASA. Therefore, it is regarded as implausible that groundwater downgradient from Landfill Area 1 would ever be used as a source of potable water. However, as an upper bound estimate of potential future risk in the unlikely event of future groundwater use, the BHHRA will evaluate residential use of groundwater immediately downgradient from Landfill Area 1. The unlikelihood of groundwater use into the foreseeable future will be discussed, if appropriate, in the uncertainties analysis.

4.3.1.5.2 Landfill Area 2

Current Site Use. Much of Landfill Area 2 is used in the agricultural production of crops for human consumption. Part of Landfill Area 2 appears to be included in a pasture area. The pasture is large and does not lend itself well to use by currently milking cattle. However, it is assumed that beef cattle or lactating dairy cattle are pastured on Landfill Area 2. Plausible receptors include a farm worker, a youthful trespasser, and a young child recreational receptor. Groundwater is not currently used in the vicinity of the site.

- ***Farm Worker.*** A farm worker may be directly exposed to surface soil while tilling the land for crop production. Potentially complete direct exposure routes include incidental ingestion, dermal contact, and inhalation of dust and volatiles. Sources of indirect exposure may include consumption of vegetables and fruits grown on site and consumption of beef and milk from cattle grazed on site.

- ***Youthful Trespasser.*** A youthful trespasser may readily gain access to Landfill Area 2 for the purpose of hiking or playing, thereby becoming directly exposed to soil. Potentially complete direct exposure routes include incidental ingestion and dermal contact with surface soil and inhalation of dust and volatiles.

- ***Young Child Recreational Receptor.*** A young child is assumed to visit Landfill 2 as a play area. The exposure routes are the same as for the youthful trespasser. The exposure parameters for this young child are the same as for resident child exposure to soil except for exposure frequency, which is the same as the youthful trespasser scenario.

The agricultural products ingested by the farm worker are assumed to be only for home use. Although such products may be sold to market, the farm worker as a home-use receptor is the most conservative and most quantifiable with respect to these items.

Future Site Use. There are no plans to develop Landfill Area 2 for any future use. However, the area is large and the surface is gently sloping but appears to be much more stable than Landfill Area 1. It is plausible to consider that the site could be developed for alternative purposes such as residential use. Plausible receptors under the future site-use scenario include the farm worker and youthful trespasser, assuming that site use does not change. Groundskeeper, resident, and construction worker scenarios are added in the event of a future decision to develop the site for alternative uses.

The water table at Landfill Area 1 is at a depth of over 200 feet, and municipal water is readily available from PRASA. Therefore, it is regarded as implausible that groundwater underlying Landfill Area 2 would ever be used as a source of potable water. However, as an upper bound estimate of potential future risk in the unlikely event of future groundwater use, the BHHRA will evaluate residential use of groundwater underlying Landfill Area 2. Groundskeeper use will also be evaluated as a potential, though highly unlikely, future long-term user of groundwater underlying the site. The unlikelihood of groundwater use into the foreseeable future will be discussed, as appropriate, in the uncertainties analysis.

- ***Farm Worker.*** The exposure scenario described for the farm worker under the current site-use scenario would apply as well to the future site-use scenario.

- ***Youthful Trespasser.*** The exposure scenario described for the youthful trespasser under the current site-use scenario would apply as well to the future site-use scenario.

- ***Young Child Recreational Receptor.*** The exposure scenario described for the young recreational child under the current site-use scenario would apply as well to the future site-use scenario.

- ***Groundskeeper.*** A groundskeeper scenario is added to the future site-use scenario to address the receptor most highly exposed to surface soil should the site be developed for commercial or industrial uses. Potentially complete direct exposure routes include incidental soil ingestion, dermal contact with soil, and inhalation of dust and volatiles. As mentioned above, the groundskeeper will also be evaluated for potential future use of groundwater underlying Landfill Area 2 and is assumed to be exposed via ingestion and dermal contact during washing.

- ***Resident***. A residential scenario is added as generally the most stringent evaluation for unrestricted use. Potentially complete direct exposure routes include incidental ingestion and dermal contact with surface soil and inhalation of dust and volatiles. Indirect exposure includes consumption of fruits and vegetables grown on site. As mentioned above, the future resident will also be evaluated for potable household uses of groundwater and is assumed to be exposed via ingestion, dermal contact during bathing/washing, and inhalation associated with household uses.

- ***Construction Worker.*** A construction worker is added as a plausible short-term scenario involving exposure to surface and subsurface soil. Potentially complete direct exposure routes include incidental ingestion, dermal contact, and inhalation of dust and volatiles.

4.3.1.5.3 Site-Specific Considerations of Soil Evaluation

Landfill Area 1. Samples to be collected at Landfill Area 1 include soil cover samples from a site-specific depth range of 0 to 2 feet bgs or until buried waste is encountered, whichever is shallower, from the area of the landfill proper, and surface soil (0 to 1 foot bgs) plus subsurface soil from the remainder of the site that consists of a narrow perimeter around the landfill proper. The soil from 0 to 2 feet bgs will be evaluated for risk as surface soil. Subsurface soil samples will be taken to determine whether contamination has migrated downward in areas outside of the landfill proper. Subsurface soil sample interval depths will be selected based on PID readings of the various intervals within the boring. The PID readings, when combined with visual inspection of test pit walls and detection of odors, will provide a guide to potential contaminant sources. Based on the instability of the terrain for development, only direct and indirect (via beef/milk ingestion) exposure to surface soil (in addition to future off-site groundwater use) will be

included in the BHHRA for Landfill Area 1. If any of the subsurface soil samples at Landfill Area 1 are collected from the near-surface interval of 1 to 3 feet bgs, analytical results of these samples will be evaluated for potential exposure via ingestion of beef. Although at a depth of 1 to 3 feet these soils would be below the root zone, the top of this interval is in close enough proximity for further consideration. Depending on the analytical results, this evaluation would likely be semiquantitative in nature and may consist of a comparison of shallow subsurface concentrations to those detected in the surface soil and/or screening concentrations. This evaluation would be included in the text of the BHHRA. Note that given the opportunity for volatilization at shallow depth ranges and the warm soil conditions associated with the tropical climate, the highest PID readings are unlikely to be detected between 1 to 3 feet bgs.

Exposure to soil at Landfill Area 1 is expected to be random across the site, because cattle graze randomly and a trespasser is likely to roam in random fashion across the entire area. Therefore, all analytical data (surface soil from the landfill proper and from the area outside the landfill proper) will be combined to yield a single data set for exposure assessment for both the current and future site-use evaluations. As mentioned in the previous paragraph, if shallow subsurface samples are collected from a depth of 1 to 3 feet bgs, these will be evaluated as appropriate, but separately from the surface soil data set. It would be noted that exposure to the shallow subsurface soil is less likely than exposure to the surface soil and discussed, if appropriate, in the uncertainties analysis.

Landfill Area 2. Samples to be collected at the Landfill Area 2 Site include soil cover samples from a site-specific depth range of 0 to 2 foot bgs or until buried waste is encountered, whichever is shallower, from the area of the landfill proper, and surface soil (0 to 1 foot bgs) plus subsurface soil (1 to 10 feet bgs) from the remainder of the site located outside of the landfill proper. The soil from 0 to 2 feet bgs will be evaluated for risk as surface soil. Human receptors to be evaluated at Landfill Area 2 include a farm worker and a youthful trespasser. The farm worker could raise crops or pasture cattle on any part of the site; therefore, it is assumed that the farm worker is exposed directly and indirectly to surface soil randomly across the entire site. Similarly, a trespasser is likely to roam randomly across the entire site. Therefore, a single data set comprising analytical data from surface soil across the entire site (the landfill proper and the area around the landfill proper) will be used for the exposure assessment for the farm worker and youthful trespasser for both the current and future site-use evaluations.

Other receptors evaluated for future site use include the groundskeeper, resident, and construction worker. Under the future site-use scenario, the area of the landfill itself could be

developed as a lawn or garden area, and the groundskeeper could be exposed randomly to soil over the landfill as well as the area around the landfill, to a depth of 2 feet. Therefore, the groundskeeper evaluation under the future site-use scenario will use a data set that combines the analytical data from the landfill proper soil cover with analytical data from the surrounding area surface soil (the same surface soil data set as used for the farm worker and youthful trespasser). Soil located above the landfill contents will be sampled to a maximum depth of 2 feet.

It is assumed that homes may be placed on the area around the landfill. While stability issues make it unlikely that homes would be placed on the landfill proper, landfill areas could be developed for lawn or garden areas. Accordingly, residential exposure will be included in risk evaluation. Two soil exposure evaluations will be performed for the resident. The first assumes that the resident is exposed only to surface soil and uses analytical data from surface soil from the area around the landfill. The second assumes that the construction of homes at the sites may redistribute subsurface soil to the surface and will use data from surface soil from the area around the landfill combined with data from subsurface soil from the area around the landfill.

Two types of construction projects are plausible at Landfill Area 2. The first could involve activities such as surface grading, landscaping, or paving, in which case the construction worker would be exposed only to surface soil. The second type of project could include building or installing utilities in the area around the landfill proper, in which case deeper excavation could be involved and the construction worker would be exposed to both surface and subsurface soil. Therefore, two construction worker evaluations will be performed. The first will use a data set that combines the analytical data from surface soil from the landfill proper with analytical data from surface soil from the area around the landfill, as described for the groundskeeper evaluation. The second will combine all surface soil and subsurface soil data that was collected from the area around the landfill.

In summary, the soil data sets used for the various Landfill Area 2 receptors are as follows:

- Combined surface soil from inside/outside landfill proper – Farm Worker, Youthful Trespasser, Groundskeeper, Construction Worker Scenario 1
- Surface soil outside landfill proper – Resident Scenario 1
- Combined surface and subsurface soil outside of landfill proper – Construction Worker Scenario 2 and Resident Scenario 2.

4.3.2 Receptor Descriptions and Exposure Assumptions

This section more fully describes the assumptions used in the exposure scenarios for the receptors identified in Section 4.3.1. The paragraphs below present exposure assumptions, parameters, and parameter values common to all or several of the receptors. The subsections that follow provide detailed descriptions and parameter values used to quantify exposure to each of the separate receptors. The exposure pathways are summarized in Table 4-1; the exposure variable values are summarized in Table 4-2.

Most BHHRAs are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989a; 1991b). It is interpreted as reflecting the 90 to 95th percentile on exposure. In keeping with EPA guidance, variables chosen for the RME evaluation for intake or contact rate, exposure frequency (EF), and exposure duration (ED) are generally upper bounds. Other variables, e.g., body weight (BW) and exposed skin surface area (SA), are generally central or average values. In the case of contact rates consisting of multiple components (e.g., dermal contact with soil, which consists of a dermal absorption factor [ABS] and soil-to-skin adherence factor [AF]), only one variable, i.e., ABS, needs to be an upper bound. The conservatism built into the individual variables ensures that the entire estimate for contact rate is more than sufficiently conservative.

The averaging time (AT) for noncancer evaluation is computed as the product of ED (years) times 365 days per year, to estimate an average daily dose over the entire exposure period (EPA, 1989a). For cancer evaluation, AT is computed as the product of 70 years, the assumed human lifetime, times 365 days per year, to estimate an average daily dose prorated over a lifetime, regardless of the frequency or duration of exposure. This methodology assumes that the risk from short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is consistent with current EPA (1986) policy of carcinogen evaluation, although it introduces considerable uncertainty into the cancer risk assessment.

A fractional term (FI) is introduced into the chemical intake equations to account for scenarios in which exposure to a potentially contaminated medium associated with the site is less than total daily exposure to that medium. For example, the youthful trespasser is expected to spend not more than half of a waking day on site potentially exposed to contaminated soil. This is reflected

in an FI of 0.5, which is introduced to adjust exposure via incidental ingestion of soil and dermal contact with soil. The default value of FI is 1.

Reference is made in the off-site consumer and farm worker receptor scenarios to consumption of “homegrown” beef, milk, fruits, and vegetables. The term “homegrown” is enclosed in quotes because these receptors do not actually live on the site; they do not maintain their residences on the site, but they use the land for production of crops for their own personal use. The resident, however, may also grow fruits and vegetables for his personal use, but since he also maintains his residence on the site, the term homegrown is not enclosed in quotes.

4.3.2.1 Off-Site Consumer of Animal Agriculture Products

The off-site consumer is a plausible receptor scenario for current and future site-use of Landfill Area 1. It is assumed that the off-site consumer is a nearby resident who ingests “homegrown” beef from cattle that are pastured on the landfill and the narrow perimeter that surrounds the landfill. Data on beef consumption are available for the United States population (EPA, 1997a) but were not located for the Puerto Rican population. Lacking data for Puerto Rico, the 90th percentile on consumption of homegrown beef for young children (0 through 6 years old) and adults from United States data are adapted for this evaluation. EPA (1997a) provides 90th percentile homegrown beef consumption rates for 12- to 69-year-old adults of 3.53 to 4.10 grams per kilogram (g/kg) BW per day (fresh weight). Assuming pre- and post-cooking food preparation losses of 51 percent (EPA, 1997a) and an adult BW of 70 kilograms (kg) (EPA, 2002), a time-weighted 90th percentile beef consumption rate for adults of 147 grams per day (g/day) is estimated, which is rounded to 150 g/day. Data regarding beef consumption by children were not located. However, EPA (1997a) provides 90th percentile home-produced meat consumption rates ranging from 7.84 to 8.68 g/kg BW per day (fresh weight). It is assumed that the majority of ingested meat is beef. Assuming pre- and post-cooking food preparation losses of 51 percent (EPA, 1997a) and that a young (0 through 6 years old) child weighs an average of 15 kg (EPA, 2002), a time-weighted 90th percentile beef consumption rate for children of 60.1 g/day is estimated, which is rounded to 60 g/day. It is conservatively assumed that 100 percent of beef consumption comes from “homegrown” sources.

This off-site consumer may plausibly ingest milk from dairy cattle grown on Landfill 1 in the future, as described in the preceding paragraph for beef cattle. Data on per capita milk consumption are available for the United States population (EPA, 1997a) but were not located for the Puerto Rico. Therefore, the estimated 90th percentile on consumption of milk for young children and adults from United States data are adapted for this evaluation. EPA (1997a)

provides a 90th percentile milk consumption rate (including only milk consumers) among all age groups of 366 g/day. This value is likely a conservative 90th percentile estimate for adults, because this study includes combined age groups (including children), and children typically consume more milk than adults (EPA, 1997a). It is noted that the 90th percentile for milk consumption from EPA (1997a) for combined ages is exactly 1.5 times the 50th percentile value of 244 g/day. A 90th percentile milk consumption value could not be found for the young child. However, EPA (1997a) lists a 50th percentile value of consumption rates for children ages 5 years and under of 441 g/day. An estimated 90th percentile milk consumption value of 662 g/day is derived by multiplying this 50th percentile value of 441 g/day by a factor of 1.5 (i.e., the ratio of the 90th percentile to the 50th percentile milk consumption rates for the combined population). It is conservatively assumed that 100 percent of milk consumption comes from "homegrown" sources.

It is assumed that the off-site consumer spends 6 years as a child and an additional 24 years as an adult (EPA, 1991b). He is exposed 350 day per year, i.e., each day that he spends at home. The beef consumption rate, when expressed on a BW basis, is higher for the child than the adult. Therefore, the noncancer hazard estimates are based only on childhood exposure. The cancer risk estimates are calculated as the sum of the risks associated with childhood and adult exposures.

4.3.2.2 Youthful Trespasser

The youthful trespasser is identified as a plausible receptor for both landfills. Potential exposure routes include incidental ingestion of soil, dermal contact with soil, and inhalation of airborne dust and volatiles. The youthful trespasser is assumed to be a nearby resident who makes regular visits to the landfills for recreational purposes. It is assumed that the youthful trespasser makes one visit per week (52 days per year) and spends 8 hours per day on site.

The youthful trespasser is assumed to be a 7- to 16-year-old youth with an average BW of 45 kg exposed for 10 years. This is the approximate average BW for a youth at age 13, which is the approximate midpoint of this age range (EPA, 1997a). An incidental soil ingestion rate of 100 milligrams per day (mg/day) is assumed for persons over 6 years of age (EPA, 1991b). The inhalation rate is assumed to be 13.5 cubic meters per day (m^3/day) (0.56 cubic meters per hour [m^3/hour]) (EPA, 1997a).

EPA (2004) recommends that dermal exposure be evaluated for adult residents based on exposure to the following parts of the body: face, hands, forearms, and lower legs. The total SA for these body parts for an average 13-year old is approximately 3,900 square centimeters (cm^2)

(EPA, 2004). Clothing provides protection against dermal contact with soil for the rest of the body. EPA (2004) recommends a value of 0.2 milligrams of soil per square centimeter of body surface (mg/cm^2) as soil to skin AF value for children. This value will be used in the BHHRA for the youthful trespasser as well

EPA (1989a) permits the development of an FI to reflect the proportion of his total daily exposure to soil that a receptor obtains from the contaminated medium. It is assumed that the 8 hours per day that the youthful trespasser spends in contact with surface soil represents a majority of his daily exposure to soil. Therefore, an FI of 1 is conservatively used for the soil exposure pathways to reflect the portion of exposure to soil that may involve on-site soil.

4.3.2.3 Farm Worker

The farm worker is identified as a plausible receptor for Landfill Area 2, because the area is currently used for crop production. Potential exposure routes include incidental ingestion of soil, dermal contact with soil, and inhalation of airborne dust and volatiles. The farm worker is assumed to be a 70-kg adult nearby resident (EPA, 1991b) with a soil ingestion rate of 100 mg/day and an inhalation rate of 2.5 m^3/hour, based on heavy activity level (EPA, 1997a). He is assumed to work on the site 8 hours/day for 250 days/year for 30 years (EPA, 1991b). EPA (2002) recommends that dermal exposure be evaluated for adult workers based on exposure to the following parts of the body: face, hands, and forearms. Given the tropical climate of Puerto Rico, the Landfill Area 1 and 2 BHHRA will also include exposure to the lower legs, assuming that the farm worker may also elect to wear shorts instead of long pants. This results in a body SA of 4,849 cm^2 (EPA, 2004), which is rounded to 5,000 cm^2. An AF value of 0.4 mg/cm^2will be used, which is the 95th percentile value for the farm worker (EPA, 2004).

It is assumed that the farm worker also consumes “homegrown” beef and milk from the site. Young children in the family would consume the same dietary items. Therefore, the adult and child beef and milk consumption scenarios previously described for the off-site consumer apply to the farm worker and the farm worker child.

In addition, the farm worker and the farm worker child may consume “homegrown” fruits and vegetables. Data on fruit and vegetable consumption are available for the United States population (EPA, 1997a) but were not located for the Puerto Rican population. Nonetheless, the 90th percentile on consumption of homegrown fruits and vegetables for young children (0 to 6 years old) and adults from United States data are adapted for this evaluation. EPA (1997a) provides 90th percentile homegrown fruit consumption rates for 12- to 69-year-old adults of 4.17

to 6.76 g/kg BW per day (fresh weight). Assuming paring and preparation losses of 21 percent (average for five fruits), moisture content of approximately 85 percent (EPA, 1997a), and an adult BW of 70 kg (EPA, 2002), a time-weighted 90th percentile fruit consumption rate for adults of 45 grams (g) dry weight per day is estimated. EPA (1997a) provides 90th percentile homegrown fruit consumption rates ranging from 6.02 to 19.3 g/kg BW per day (fresh weight) for young children. Assuming preparation losses of 21 percent, moisture content of approximately 85 percent (EPA, 1997a), and a young child BW of 15 kg (EPA, 2002), a time-weighted 90th percentile fruit consumption rate for children of 20 g dry weight per day is estimated. Cooking losses were not included in these estimations; it is assumed fruits are eaten raw.

EPA (1997a) provides 90th percentile homegrown vegetable consumption rates for 12- to 69-year-old adults of 3.44 to 5.12 g/kg BW per day (fresh weight). Assuming preparation losses of 17 percent (average of 11 vegetables that may contribute substantially to total vegetable intake), moisture content of approximately 81 percent (same 11 vegetables) (EPA, 1997a), and an adult BW of 70 kg (EPA, 2002), a time-weighted 90th percentile vegetable consumption rate for adults of 48 g dry weight per day is estimated. EPA (1997a) provides 90th percentile homegrown vegetable consumption rates ranging from 6.35 to 13.1 g/kg BW per day (fresh weight) for young children. Assuming preparation losses of 17 percent (see previous reference), moisture content of approximately 81 percent (EPA, 1997a), and a young child BW of 15 kg (EPA, 2002), a time-weighted 90th percentile fruit consumption rate for children of 21 g dry weight per day is estimated.

It is conservatively assumed that 100 percent of fruit and vegetable consumption comes from “homegrown” sources.

The adult farm worker is assumed to be directly exposed to soil while working on the Landfill Area 2 site for 30 years, which is the upper bound for residential location in one place in the United States (EPA, 1991b). In addition, it is assumed that he consumes “homegrown” beef, milk, fruits, and vegetables on each of the 350 days the resident is expected to spend at home. The farm worker child, on the other hand, is not directly exposed to soil at the Landfill Area 2 site. He does, however, consume “homegrown” beef, milk, fruits, and vegetables 350 days per year for 6 years. Separate cancer risk and noncancer hazard estimates are calculated for the adult farm worker and the child farm worker. The estimates for the child and adult farm workers are not summed because the direct exposure pathways pertain only to the adult.

4.3.2.4 Groundskeeper

The groundskeeper is a plausible receptor for Landfill Area 2 under a future land-use scenario. The groundskeeper is a site worker who spends the majority of his time outdoors tending yards and gardens, trimming shrubs, and performing other general outdoor duties. Potential exposure routes include incidental ingestion of soil, dermal contact with soil, and inhalation of airborne dust and volatiles. The groundskeeper is assumed to be a 70-kg adult (EPA, 2002) with a soil ingestion rate of 100 mg/day and an inhalation rate of 2.5 m^3/hour, based on heavy activity level (EPA, 1997a). He is assumed to work on the site 8 hours/day on 5 days/week for 225 days/year for 25 years (EPA, 2002). An exposed skin SA of 5,000 mg/cm^2 will be assumed, based on the exposure to the face, forearms, hands, and lower legs, as described in Section 4.3.2.3 for the farm worker. An AF value of 0.1 mg/cm^2will be used in the BHHRA, which is the 95th percentile value for the groundskeeper (EPA, 2004).

Because groundwater is being investigated, exposure to groundwater will be evaluated for the groundkeeper as a possible, though not plausible, long-term receptor in the BHHRA. His drinking water ingestion rate is assumed to be 2 liters per day (L/day) (EPA, 2002). He may also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it was assumed that the face, forearms, and hands, approximately 3,300 cm^2 (EPA, 2004), would be exposed intermittently for up to 0.5 hour per day. Because exposure was assumed to be intermittent, rather than continuous, organic chemical uptake across the dermis would not reach steady state, which guides selection of the EPA (2004) model to be used to quantify this pathway (Section 4.3.4.9).

4.3.2.5 Resident

The resident is a plausible receptor for Landfill Area 2 under a future land-use scenario. Potential direct exposure routes include incidental ingestion of soil, dermal contact with soil, and inhalation of airborne dust and volatiles. In addition, the resident may maintain some fruit trees and plant a vegetable garden. Therefore, the fruit and vegetable ingestion scenarios developed for the farm worker adult and child apply also to the resident.

Assessment of residential exposure involves evaluating both an adult and a child. The adult evaluation captures the conservatism associated with a longer ED, because an individual resident spends more time as adult than child. The child evaluation, however, captures the conservatism associated with greater ingestion and inhalation rates, at least when normalized for BW. The cancer risk estimates are calculated as the sum of the risk associated with childhood and adult exposures.

The adult resident is assumed to weigh 70 kg (EPA, 1991b), have a soil incidental ingestion rate of 100 mg/day (EPA, 2002), and have an inhalation rate of 15 m^3/day (0.63 m^3/hour) (EPA, 1997a). The EF and ED for the adult resident are assumed to be 350 days/year and 24 years, respectively (EPA, 2002). EPA (2002) recommends that dermal exposure be evaluated for adult residents based on exposure to the following parts of the body: face, hands, forearms, and lower legs. This results in a body SA of 4,849 cm^2 (EPA, 2004), which is rounded to 5,000 cm^2. EPA (2004) recommends a default AF value of 0.07 mg/cm^2 for the adult resident; this value will be used in the BHHRA.

The child resident is assumed to be 1 through 6 years of age, weigh 15 kg, have a soil incidental ingestion rate of 200 mg/day (EPA, 2002), and have an inhalation rate of 8.3 m^3/day (0.35 m^3/hour) (EPA, 1997a). The EF and ED for the child resident are assumed to be 350 days/year and 6 years, respectively (EPA, 2002). EPA (2002) recommends that dermal exposure be evaluated for child residents based on exposure to the following parts of the body: face, hands, forearms, lower legs, and feet. This results in a body SA of 2,514 cm^2 (EPA, 2004), which is rounded to 2,500 cm^2. EPA (2004) recommends a default AF value of 0.2 mg/cm^2 for the child resident; this value will be used in the BHHRA.

Although future groundwater use is regarded as implausible, exposure to groundwater will be evaluated for the resident as an upper-bound exposure estimate in the BHHRA. Drinking water ingestion rates for the adult of 2 L/day and for the child of 1 L/day (EPA, 1991b) will be assumed. Both the child and adult resident are assumed to be dermally exposed to COPCs in groundwater while bathing/showering. The child will be assumed to bathe for one hour per day, and the adult will be assumed to shower for 0.58 hour per day (35 minutes/day) (EPA, 2004a). Because the *Exposure Factors Handbook* (EPA, 1997a) lists a 90th percentile for time spent in a residence as over 23 hours per day, it will be conservatively assumed that the resident spends 24 hours per day in the house.

4.3.2.6 Young Child Recreational Receptor

A young child (ages 1 through 6 years) is assumed to visit the site for recreational play. This receptor is assumed to be exposed to surface soil via incidental ingestion, dermal contact, and inhalation of airborne dust and volatiles originating from soil. This young child is assumed to frequent the site once per week (52 days/year) for 8 hours per day. Other exposure parameters are assumed to be the same as those for child resident with respect to soil exposure (Section 4.3.2.5).

4.3.2.7 Construction Worker

The construction worker is introduced as a plausible scenario for direct exposure to surface soil at Landfill Area 2 and for exposure to surface and subsurface soil in the area around the perimeter of Landfill Area 2. Potential exposure routes include incidental ingestion of soil, dermal contact with soil, and inhalation of airborne dust and volatiles. In a future site-use scenario, the construction worker is involved in a short-term (hypothetical one year) construction project that includes excavation and grading of soil. The groundskeeper is assumed to be a 70-kg adult (EPA, 2002) with a soil ingestion rate of 330 mg/day and an inhalation rate of 2.5 m^3/hour, based on heavy activity level (EPA, 2002). He is assumed to work on the site 8 hours/day at the rate of 225 days/year for (EPA, 2002) for 1 year (i.e., total of about 225 working days). An exposed skin SA of 5,000 mg/cm^2 will be assumed, based on the exposure to the face, forearms, hands, and lower legs, as described in Section 4.3.2.3 for the farm worker. An AF value of 0.3 mg/cm^2will be used in the BHHRA, which is the 95th percentile value for the construction worker (EPA, 2004).

4.3.3 Quantification of Exposure-Point Concentrations

The EPC is an estimate of the concentration of a COPC in a given medium to which a receptor may be exposed over the duration of the exposure. An EPC may be based on media concentrations that have been directly measured, or it may be derived based on environmental medium-to-medium transport modeling. For the Landfill Areas 1 and 2 BHHRA, the EPCs of COPCs in soil and groundwater will be statistically derived values, based on measured analytical data. Concentrations of COPCs in air and food items will not be measured (and in some cases cannot reasonably be measured) but will be based on models, which use the EPC of the measured environmental media as input values. The following subsections describe the statistical approaches and the models used to derive EPCs for each environmental medium.

4.3.3.1 Exposure-Point Concentrations in Measured Environmental Media

Generally, the 95th percent UCL or the MDC of the measured concentrations, whichever is lower, will selected as the EPC for soil or groundwater. This value is understood to represent a conservative estimate of average concentration for use in the exposure assessment for RME evaluation.

Exposure to an environmental medium is generally assumed to be random, and the EPC should be the arithmetic average encountered over the exposure duration (EPA, 1989a). Therefore, the population mean concentration, if known, would be the ideal value selected as the EPC. The

sample mean is an obvious estimate of the population mean. However, uncertainties exist as to how well the sample mean represents the population mean. Therefore, EPA (1989a; 2007b) has recommended the inclusion of a UCL of 95 percent on the mean for RME evaluation.

The UCL is estimated by employing statistical calculations on the sample data set. The type of calculation performed is dependent on type of distribution, variability, skewness, and size of the sample data set. For the BHHRA, the ProUCL Version 4.0 software program (EPA, 2007c) will be used to determine distribution type and various calculated estimates of the UCL based on distribution type. ProUCL 4.0 has a built-in UCL selection matrix, which yields one or more recommendations. A simplified version of the ProUCL 4.0 matrix is as follows:

1. If data pass the test for normal distribution (W-test for normality), the UCL based on the Student's t calculation is recommended.

2. If not are not normally distributed, but the data pass the test for gamma distribution (Anderson-Darling), then the UCL based on gamma distribution is recommended.

3. If the data fail the tests for normal and gamma distribution, but pass the test for lognormality (W-test for lognormality), a UCL based on the lognormal distribution is recommended (generally these calculations are based on either the H-statistic or a variation of the Chebyshev inequality method), unless the variation is sufficiently low to recommend a UCL based on the Student's t calculation.

4. If the data fail all distribution tests, then a UCL based on a nonparametric method is recommended (generally these calculations are based on a variation of the Chebyshev inequality method or bootstrapping method), unless the skewness is sufficiently low to recommend a UCL based on the Student's t calculation.

Further details on the above decision matrix are provided in the *ProUCL Version 4.0 Technical Guide* (EPA, 2007d).

Analytical results are presented as "nondetects" ("U" qualifier) whenever chemical concentrations in samples do not exceed the reporting limits for the analytical procedures for those samples. Generally, the reporting limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. ProUCL Version 4.0 uses Kaplan-Meier statistical methods to evaluate data sets with nondetects (EPA, 2007b). In cases where matrix interference or other phenomena drive the reporting limit unusually high for nondetects, judgment will be reserved to remove these nondetected data from the data set. If any nondetects are eliminated from a data set due to high reporting limits that would otherwise skew the EPC, these samples will be discussed in the uncertainties analysis of the BHHRA.

4.3.3.2 Exposure-Point Concentrations in Ambient Air

Exposure to airborne dust and VOCs from soil is a potential exposure pathway for the youthful trespasser, farm worker, groundskeeper, resident, and construction worker. Two phenomena give rise to dust in the air to which a receptor might be exposed:

- Receptor activity on the site
- Action of the wind.

Airborne dust to which the construction worker and farm worker would be exposed may more likely be resultant from the nature of their activities rather than the action of the wind, because these receptors would operate equipment that raises dust. Conversely, the other receptors are more likely to be exposed to dust primarily raised by wind erosion. EPA (2002) assumes that a resident and an outdoor worker such as a groundskeeper would be exposed to fugitive dusts via wind erosion but that a construction worker would be exposed to fugitive dusts primarily through construction activities. Activities associated with farming, notably tilling, also create dust that may that may be inhaled by farm workers.

In the BHHRA, it will be assumed that the construction worker is exposed under a construction scenario and that construction vehicle traffic on unpaved roads is the primary source of dust (EPA, 2002). It will also be assumed that the farm worker will be exposed via tilling and the inhalation of dust via wind erosion, using a model described by EPA (2002). For all other receptors which are evaluated for exposure via dust inhalation, this dust is assumed to arise primarily from wind erosion (EPA, 2002).

EPA (2002) has developed model to estimate dust particulate emission factors (PEF) under a variety of scenarios (e.g., wind erosion, particulates resulting from vehicle traffic or various activities) based on an "unlimited reservoir" model and the assumption that the source area is square. The following equation will be used to estimate the PEF for the construction worker (EPA, 2002) at Landfill 2.

$$\boldsymbol{PEF_{scr}} = \boldsymbol{Q/C}_{sr} \times \frac{\mathbf{1}}{\boldsymbol{F_D}} \times \left[\frac{\boldsymbol{T \times A_R}}{\mathbf{566} \times \left(\frac{\boldsymbol{W}}{\mathbf{3}}\right)^{\mathbf{0.4}} \times \frac{\left(\frac{\mathbf{365}\boldsymbol{d}}{\boldsymbol{yr}} - \boldsymbol{p}\right)}{\frac{\mathbf{365}\boldsymbol{d}}{\boldsymbol{yr}}} \times \sum \boldsymbol{VKT}} \right] \qquad \text{Eq. 1}$$

Where:

PEF_{scr} = Subchronic road particulate emission factor cubic meters per kilogram (m^3/kg), calculated

Q/C_{sr} = Inverse of the ratio of the 1-h geometric mean air concentration to the emission flux along a straight road segment bisecting a square site grams per square meter per second (g/m^2-s) per kilograms per cubic meter (kg/m^3), calculated

F_D = Dispersion correction factor (unitless)

T = Total duration over which construction occurs in seconds (s) (31,536,000 s equals 1 year)

A_r = Surface area of contaminated road segment (m^2); equals $L_R \times W_R \times 0.092903$ square meter per square foot

L_r = Length of road segment (feet)

W_r = Width of road segment (feet)

W + Mean vehicle weight (tons)

p = Number of days annually with at least 0.01 inch of precipitation (days/year)

∑VKT = Sum of fleet vehicle kilometers traveled during the exposure duration (kilometers).

The PEF for the Landfill 2 farm worker will be estimated using the following equation from EPA (2002). The time-average unit emission flux (J_T) described below for construction activities will be based on wind erosion and tilling as described in Appendix E of EPA (2002).

$$\boldsymbol{PEF_{sa}} = \frac{\boldsymbol{Q}}{\boldsymbol{C_{sa}}} \times \frac{\boldsymbol{1}}{\boldsymbol{F_D}} \times \frac{\boldsymbol{1}}{\langle \boldsymbol{J_T} \rangle} \qquad \text{Eq. 2}$$

Where:

PEF_{sct}	=	Subchronic particulate emission factor for tilling and wind erosion (m^3/kg), averaged over 1 year. Calculated as in Equations E-20 and E-25 from EPA (2002).
Q/C_{sa}	=	Inverse of the ratio of the 1-hour geometric mean air concentration and the emission flux at the center of the square emission source (g/m^2-s per kg/m^3), calculated using Equation E-15 from EPA (2002).
F_D	=	Dispersion correction factor (unitless), calculated using equation E-16 from EPA (2002)
$<J_T>$	=	Total time average PM_{10} unit emission flux for tilling and wind erosion (g/m^2-s), calculated using Equation E-25 of EPA (2002).

As discussed above, the receptors other than the construction worker and farmer are most likely to be exposed to dust resulting primarily from wind erosion rather than dust-raising activities. The PEF for the remaining receptors exposed to dust (on-site resident, groundskeeper, youthful trespasser, and young recreational child) is calculated using the following equation (EPA, 2002). Note that separate wind-erosion PEF values will be calculated for Landfill 1 and Landfill 2.

$$PEF_{wind} = Q/C_{wind} \times \frac{3600}{0.036 \times (1-V) \times (U_m / U_t)^3 \times F(x)} \qquad \text{Eq. 3}$$

where:

PEF_{wind} = particulate emission factor associated with wind erosion(m^3/kg, calculated)
Q/C_{wind} = inverse of the mean concentration at center of square source (g/m^2-second per kg/m^3, value calculated from Exhibit E-3 (assume Miami, Florida) and Equation E-4 in EPA [2002])
3600 = seconds/hour
V = fraction of surface covered with vegetation (0.5, unitless, default)
U_m = mean annual wind speed (site-specific or default, 4.69 meters per second [m/s])
U_t = equivalent threshold value of wind speed at 7 m (site-specific or default, 11.32 m/s)
F(x) = function dependent on U_m/U_t (default 0.194).

Miami, Florida, is selected as most closely approximating meteorological conditions at the Base because of its coastal location.

The concentration of a COPC in air is calculated using any of the three types of PEF values (i.e., PEF_{scr}, PEF_{sct}, and PEF_{wind}) as follows:

$$C_a = \frac{C_s}{PEF} \qquad \text{Eq. 4}$$

where:

C_a = contaminant concentration in air (milligrams per cubic meter [mg/m^3], calculated)
C_s = contaminant concentration in soil (milligrams per kilogram [mg/kg])
PEF = particulate emission factor (m^3/kg, calculated).

Exposure to VOCs released from soil is a plausible exposure scenario for any of the receptors directly exposed to surface or subsurface soil. Unless surface soil is recently contaminated, concentrations of VOCs in the first few inches of undisturbed surface soil generally are low, having dissipated with time, so that airborne concentrations of VOCs from ongoing volatilization are negligible. The levels of VOCs in soil more than a few inches deep, however, can be substantial, so that airborne concentrations could be significant.

EPCs of VOCs in ambient air due to volatilization from soil are estimated with a chemical-specific soil volatilization factor calculated from the following equations and defaults provided by EPA (1996):

$$VF_s = Q/C_{vol} \bullet CF_2 \bullet \left(\frac{[\,3.14 \bullet D_A \bullet T\,]^{1/2}}{2 \bullet \rho_b \bullet D_A} \right) \qquad \text{Eq. 5}$$

and

$$D_A = \frac{(\theta_a^{10/3} \bullet D_i \bullet H' + \theta_w^{10/3} \bullet D_W\,)\,/\,n^2}{\rho_b \bullet K_d + \theta_w + \theta_a \bullet H'} \qquad \text{Eq.6}$$

where:

VF_s	=	chemical-from-soil volatilization factor (m^3/kg, chemical-specific, calculated)
Q/C_{vol}	=	inverse of the ratio of the geometric mean air concentration to the volatilization flux at the center of the square source; value calculated from Exhibit D-3 (assume Miami, Florida) in EPA, 2002)
CF_2	=	conversion factor (10^{-4} square meters (m^2) per cm^2)
D_A	=	apparent diffusivity (square centimeters per second [cm^2/second, calculated)
T	=	exposure interval (seconds, estimated as ED 3.15E7 seconds per year)
ED	=	exposure duration (years, receptor-specific)
ρ_b	=	dry soil bulk density (site-specific or default 1.5 grams per cubic centimeter [g/cm^3])
θ_a	=	air-filled soil porosity (site-specific estimated as n - θ_w or default 0.28 unitless)
n	=	total soil porosity (site-specific estimated as 1-[ρ_b/ρ_s] or default 0.43 unitless)
ρ_s	=	true soil or particle density (site-specific or default 2.65 g/cm^3)
θ_w	=	water-filled soil porosity (site-specific or default 0.15 L_{water}/L_{soil})
D_i	=	diffusivity in air (cm^2/second, chemical specific)
H'	=	dimensionless Henry's law constant (chemical specific, may be estimated as H x 41)

H	=	Henry's law constant (atmospheres per cubic meter per mole [atmosphere-m^3/mole], chemical specific)
D_W	=	diffusivity in water (cm^2/second, chemical-specific)
K_d	=	soil-water partition coefficient (cubic centimeters per gram [cm^3/g], chemical-specific, may be estimated as K_{oc} x f_{oc})
K_{oc}	=	soil organic carbon-water partition coefficient (cm^3/g, chemical-specific)
f_{oc}	=	organic carbon content of soil (site-specific or default 0.006 g/g).

The concentration of chemical in the air is calculated as follows:

$$C_a = \frac{C_s}{VF_s} \qquad \text{Eq. 7}$$

where:

C_a	=	chemical concentration in air (mg/m^3, calculated)
C_s	=	COPC EPC in soil (mg/kg)
VF_s	=	chemical-from-soil volatilization factor (m^3/kg).

Site-specific data will be used for as many variables as possible; defaults from various EPA guidance documents will be used where site-specific data are not available.

4.3.3.3 Exposure-Point Concentrations in Fruits and Vegetables

The potential for fruit and vegetable items to accumulate COPCs is considered for metals and SVOCs; VOCs are generally too mobile and labile to contribute significantly to food-chain pathways. COPC concentrations in fruits and vegetables are estimated from the following equation:

$$C_p = (C_s)(B_p) \qquad \text{Eq. 8}$$

where:

C_p	=	concentration of contaminant in vegetable or fruit dry matter (mg/kg, calculated)
C_s	=	COPC EPC in soil (mg/kg)
B_p	=	soil-to-plant biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

C_p will be expressed C_{pv} for vegetables and C_{pr} for fruit. Values of B_p for metals will be taken from Baes, et al. (1984); values for the vegetative parts of plants (B_{pv}) will be used for vegetables

and values for the reproductive parts of plants (B_{pr}) will be used for fruits. Values of B_p for SVOCs will be calculated using the following equation (Travis and Arms, 1988):

$$\log B_p = 1.588 - 0.578 \log K_{ow} \qquad \text{Eq. 9}$$

where:

$\log B_p$	=	soil-to-plant biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil, calculated)
K_{ow}	=	octanol-water partition coefficient.

4.3.3.4 Exposure-Point Concentrations in Beef

The potential for beef to accumulate COPCs is considered for metals and SVOCs; VOCs are generally too mobile and labile to contribute significantly to food-chain pathways. It is assumed that beef cattle graze on pasture growing on potentially contaminated soil and that pasture provides 100 percent of forage intake, which is equivalent to 8.8 kg forage dry matter per day (EPA, 1998). During grazing, cattle are assumed to ingest 0.5 kg of soil per day (EPA, 1998). Estimation of COPC concentrations in beef is a two-step process. The first step, estimation of COPC concentrations in forage, is accomplished by the following equation:

$$C_f = (C_s)(B_p) \qquad \text{Eq. 10}$$

where:

C_f	=	concentration of contaminant in forage (pasture grasses) dry matter (mg/kg, calculated)
C_s	=	COPC EPC in soil (mg/kg)
B_p	=	soil-to-plant biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

Values of B_p for metals will be taken from, Baes, et al. (1984); values for the vegetative parts of plants (B_{pv}) will be used for pasture grasses. Values of B_p for SVOCs will be calculated using the previous equation from Travis and Arms (1988).

The second step, estimating COPC concentrations in beef, is accomplished by the following equation:

$$C_b = [(C_f)(Qf)(F_i) + (Qs)(C_s)]\,(Bb)(MF) \qquad \text{Eq. 11}$$

where:

C_b	=	concentration of contaminant in edible beef tissue (mg/kg, calculated)
C_f	=	concentration of contaminant in forage (pasture grasses) dry matter (mg/kg)
F_i	=	Fraction of forage grown on contaminated soil
Qf	=	beef cattle forage dry matter ingestion rate (8.8 kg/day)
Qs	=	beef cattle soil ingestion rate (0.5 kg/day)
C_s	=	COPC EPC in soil (mg/kg)
Bb	=	beef biotransfer factor (mg of chemical per kg of edible beef tissue)
MF	=	metabolism factor, chemical-specific (unitless).

4.3.3.5 Exposure-Point Concentrations in Milk

The potential for milk to accumulate COPCs is considered for metals and SVOCs; VOCs are generally too mobile and labile to contribute significantly to food-chain pathways. It is assumed that dairy cattle graze on pasture growing on potentially contaminated soil and that pasture provides 100 percent of forage intake, which is equivalent to 13.2 kg forage dry matter per day (EPA, 1998). During grazing, cattle are assumed to ingest 0.4 kg of soil per day (EPA, 1998). Estimation of COPC concentrations in milk is a two-step process. The first step, estimation of COPC concentrations in forage, is accomplished by the following equation:

$$C_f = (C_s)(B_p) \qquad \text{Eq. 12}$$

where:

C_f	=	concentration of contaminant in forage (pasture grasses) dry matter (mg/kg, calculated)
C_s	=	COPC EPC in soil (mg/kg)
B_p	=	soil-to-plant biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

Values of B_p for metals will be taken from, Baes, et al. (1984); values for the vegetative parts of plants (B_{pv}) will be used for pasture grasses. Values of B_p for SVOCs will be calculated using the previous equation from Travis and Arms (1988).

The second step, estimating COPC concentrations in milk, is accomplished by the following equation:

$$C_b = [(C_f)(Qf)(F_i) + (Qs)(C_s)]\,(Bm)(MF) \qquad \text{Eq. 13}$$

where:

C_m	=	concentration of contaminant in milk issue (mg/kg, calculated)
C_f	=	concentration of contaminant in forage (pasture grasses) dry matter (mg/kg)
F_i	=	Fraction of forage grown on contaminated soil
Qf	=	dairy cattle forage dry matter ingestion rate (13.2 kg/day)
Qs	=	dairy cattle soil ingestion rate (0.4 kg/day)
C_s	=	COPC EPC in soil (mg/kg)
Bm	=	milk biotransfer factor (mg of chemical per kg of milk)
MF	=	metabolism factor, chemical-specific (unitless).

4.3.3.6 Concentrations in Shower Room Air from Groundwater Use

Inhalation of VOCs released from groundwater and used as tap water will be evaluated, if applicable, for the on-site and off-site resident scenarios. Chemicals that have a Henry's Law value exceeding 1E-05 atmosphere-m^3/mole and a molecular weight less than 200 grams per mole are considered to be VOCs and are subject to evaluation via this pathway. Other groundwater contaminants may be evaluated on a case-by-case basis for their potential contribution to risk via the inhalation pathway based on the degree of departure from the Henry's Law and molecular weight criteria, groundwater concentration, and toxicity.

The Andelmam (1990) model as modified by Schaum, et al. (1994), is used to estimate the air concentrations of VOCs released from tap water during showering. Note that groundwater is assumed in the BHHRA to be used as residential tap water. A showering model is used for the inhalation pathway because exposure to VOC vapors released from tap water is generally greatest during showering, The Schaum et al. (1994), model is represented by the following equations. Note that parameter values are from Schaum et al. (1994), except as noted.

$$C_a = ((C_{a_max}/2) \times t_1 + (C_{a_max} \times t_2))/(t_1 + t_2) \qquad \text{Eq. 14}$$

where:

C_a	=	Modeled VOC concentration in shower room air (mg/m^3)
$C_{_max}$	=	Maximum VOC concentration attained in shower room during shower/post-shower time (mg/m^3)
t_1	=	Shower duration (0.58 hour, EPA, 2004)
t_2	=	Time spent in shower room after showering (estimated at 0.33 hour based on Schaum et al., [1994]).

The maximum VOC concentration attained in the shower room (C_{a_max}) is estimated using the following equation:

$$C_{a_max} = \frac{C_{gw} \times fv \times FR \times t_1}{V} \qquad \text{Eq. 15}$$

where:

$C_{_max}$	=	Maximum VOC concentration attained in shower room during shower/post-shower time (mg/m3)
C_{gw}	=	EPC of VOC in groundwater (milligrams per liter [mg/L])
fv	=	fraction in groundwater volatilized (0.75 [unitless], Schaum et al. [1994])
FR	=	water flow rate (12.5 liters per minute, Schaum et al. [1994])
t_1	=	Shower duration (0.58 hour, EPA, 2004)
V	=	shower room volume (estimated at 6 m3, based on Schaum et al. [1994]).

Note that this model is designed as a closed system. That is, it assumes no ventilation either via a ventilation fan, window, or an open shower room door throughout the 35-minute shower duration and the 20-minute post-showering duration.

4.3.3.7 Concentrations of VOCs in Groundwater: Resident Dermal Uptake

Volatilization of VOCs from household water during showering reduces the concentration remaining available for dermal contact (Andelman, 1990; Schaum et al., 1994; EPA, 1991c). Experiments conducted using TCE and chloroform resulted in a water-to-air transfer efficiency of 50 to 90 percent during showering (Andelman, 1990). Schaum et al. (1994), recommend a time-weighted average residual concentration factor of 0.6 for dermal exposure.; in plain terms, Schaum et al. (1994), recommend that a value 0.6 times the initial average of the initial concentration being volatilized. Thus, the concentrations of VOCs remaining in the water after volatilization occurs is calculated as follows:

$$C_d = C_{gw} \bullet F_{dc} \qquad \text{Eq. 16}$$

where:

C_d	=	concentration of VOC in household water available for dermal exposure (mg/L, calculated)
C_{gw}	=	EPC of VOC in groundwater (mg/L)
F_{rd}	=	fraction of initial VOC concentration which does not volatilize and is available for dermal contact (0.6, unitless).

Only the concentration remaining in tap water after volatilization (C_d), as applicable, is assumed to be available for contact with the skin during showering. Note that because only the adult is

assumed to shower, the calculation of C_d above applies only to the adult receptor. The young child is assumed to be dermally exposed to the full groundwater EPC while bathing.

4.3.4 Quantification of Chemical Intake Rates

This section describes the models used to quantify doses or intakes of the COPCs by the receptors and exposure pathways previously identified. The intake model variables generally reflect 50th or 95th percentile values, which, when applied to the EPCs derived as described previously, ensure that the estimated intake rates represent the RME.

Models were taken or modified from EPA (1989a) unless otherwise indicated.

4.3.4.1 Inhalation of COPCs in Air

All receptors except the off-site consumer and the farm worker child may be exposed to airborne dust and VOCs from soil. The inhaled dose of a COPC in air is estimated as follows:

$$I_a = \frac{(C_a)(IR_a)(FI_a)(ET_a)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 17}$$

where:

I_a	=	inhaled dose of COPC (milligrams per kilogram per day [mg/kg-day], calculated)
C_a	=	EPC of COPC in air (mg/m^3)
IR_a	=	inhalation rate (m^3/hour)
ET_a	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.2 Incidental Ingestion of COPCs in Soil

All receptors except the off-site consumer and the farm worker child may be exposed to soil by incidental ingestion. The ingested dose of a COPC in soil is estimated from the equation:

$$I_s = \frac{(C_s)(IR_s)(FI_s)(EF)(ED)(CF_3)}{(BW)(AT)} \qquad \text{Eq. 18}$$

where:

I_s	=	ingested dose of COPC in soil (mg/kg-day, calculated)
C_s	=	EPC of COPC in soil (mg/kg)

IR_s	=	soil incidental ingestion rate (mg/day)
FI_s	=	fraction of daily soil exposure attributed to site (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF_3	=	conversion factor (1E-6 kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.3 Dermal Contact with COPCs in Soil

All receptors except the off-site consumer and the farm worker child may be exposed to soil by dermal contact. Unlike the methodologies for estimating inhaled or ingested dose of COPCs, which quantify the dose presented to the barrier membrane (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as the dose that crosses the skin and is systemically absorbed. For this reason, dermal toxicity values are also based on absorbed dose. The absorbed dose of a COPC is estimated as follows (EPA, 2004):

$$DAD = \frac{(DA)(SA)(FI_d)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 19}$$

where:

DAD	=	average dermally absorbed dose of COPC (mg/kg-day, calculated)
DA	=	dose absorbed per unit body surface area per day (mg/cm^2)
SA	=	body surface area exposed to soil (cm^2/day)
FI_d	=	fraction of daily soil exposure attributed to site (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days).

It is assumed that one exposure event occurs each exposure day to maintain the dimensional integrity of the equation.

Dermal uptake of COPCs from soil assumes that absorption is a function of the fraction of a dermally applied dose that is absorbed. It is calculated from the following equation (EPA, 2004):

$$DA = (C_s)(CF_3)(AF)(ABS) \qquad \text{Eq. 20}$$

where:

DA	=	dose absorbed per unit body surface area per day (mg/cm^2,

		calculated)
C_s	=	EPC of COPC in soil (mg/kg)
CF_3	=	conversion factor (1E-6 kg/mg)
AF	=	soil-to-skin adherence factor (mg/cm^2)
ABS	=	dermal absorption fraction (unitless, chemical-specific value).
AT	=	averaging time (days).

4.3.4.4 Ingestion of COPCs in Beef

The off-site consumer and the farm worker may be indirectly exposed to soil by consumption of "homegrown" beef. The ingested dose of a COPC in beef is estimated from the equation:

$$I_b = \frac{(C_b)(IR_b)(FI_b)(EF)(ED)(CF_4)}{(BW)(AT)} \qquad \text{Eq. 21}$$

where:

I_b	=	ingested dose of COPC in beef (mg/kg-day, calculated)
C_b	=	EPC of COPC in edible beef tissue (mg/kg)
IR_b	=	beef ingestion rate (g/day)
FI_b	=	fraction of beef "homegrown" (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF_4	=	conversion factor (1E-3 kg/g)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.5 Ingestion of COPCs in Milk

The off-site consumer and the farm worker may be indirectly exposed to soil by consumption of "homegrown" milk. The ingested dose of a COPC in milk is estimated from the equation:

$$I_m = \frac{(C_m)(IR_m)(FI_m)(EF)(ED)(CF_4)}{(BW)(AT)} \qquad \text{Eq. 22}$$

where:

I_m	=	ingested dose of COPC in milk (mg/kg-day, calculated)
C_m	=	EPC of COPC in milk (mg/kg)
IR_b	=	milk ingestion rate (g/day)
FI_b	=	fraction of milk "homegrown" (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF_4	=	conversion factor (1E-3 kg/g)
BW	=	body weight (kg)

AT = averaging time (days).

4.3.4.6 Ingestion of COPCs in Fruits and Vegetables

The off-site consumer and the farm worker may be indirectly exposed to soil by consumption of "homegrown" fruits and vegetables. The ingested dose of a COPC in fruits and vegetables is estimated from the equation:

$$I_p = \frac{\left[(C_{pv})(IR_v) + (C_{pr})IRr)\right](FI_p)(EF)(ED)(CF_4)}{(BW)(AT)} \qquad \text{Eq.23}$$

where:

I_p	=	ingested dose of COPC in plants (fruits and vegetables) (mg/kg-day, calculated)
C_{pv}	=	EPC of COPC in vegetable dry matter (mg/kg)
IR_v	=	vegetable dry matter ingestion rate (g/day)
C_{pr}	=	concentration of contaminant in fruit dry matter (mg/kg)
IR_r	=	fruit dry matter ingestion rate (g/day)
FI_p	=	fraction of fruits and vegetables "homegrown" (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF_4	=	conversion factor (1E-3 kg/g)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.7 Ingestion of COPCs in Groundwater

The ingested dose of a COPC in groundwater is estimated from the equation:

$$I_w = \frac{(C_w)(IR_w)(FI_w)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 24}$$

where:

I_w	=	ingested dose of COPC in groundwater (mg/kg-day, calculated)
C_w	=	EPC of COPC in groundwater (mg/L)
IR_w	=	drinking water ingestion rate (L/day)
FI_w	=	fraction of exposure attributed to site groundwater (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.8 Inhalation of COPCs from Air

The following equation is used to estimate the inhaled dose of a COPC in air as a result of volatilization from tap water. Air concentrations used in this equation are modeled.

$$I_{sa} = \frac{(C_a)(IR_a)(ET_a)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 25}$$

where:

I_a	=	inhaled dose of COPC (mg/kg-day, calculated)
C_a	=	EPC of COPC in air from dust and volatilization (mg/m^3)
IR_a	=	inhalation rate (m^3/hour)
ET_a	=	exposure time to VOCs in air (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days).

4.3.4.9 Dermal Contact with COPCs in Water

Unlike the methodologies for estimating inhaled or ingested doses of a COPC, which quantify the dose presented to the barrier membrane (the pulmonary or gastrointestinal mucosa, respectively), the dermal dose is estimated as the dose that crosses the skin and is systematically absorbed. For this reason, dermal toxicity values are also based on absorbed dose. The absorbed dose of COPCs from groundwater are estimated using the following equation (EPA, 2004):

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 26}$$

where:

DAD	=	average dermally absorbed dose of COPC (mg/kg-day, calculated)
DA	=	dose absorbed per unit body surface area per event (milligrams per square centimeter per event [mg/cm^2-event])
SA	=	surface area of the skin available for contact with groundwater (cm^2)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days).

Quantification of dermal uptake of constituents from water depends on a permeability coefficient (K_p), which describes the rate of movement of a constituent from water across the dermal barrier to the systemic circulation (EPA, 2004). Separate calculation methods are applied to estimate the dose absorbed (DA) term (defined above) for inorganic and organic chemicals in water. For inorganic chemicals, DA is calculated from the following equation:

$$DA = (C_w)(K_p)(ET_w)(CF) \qquad \text{Eq. 27}$$

where:

DA	=	dose absorbed per unit body surface area per event (mg/cm^2-event, calculated)
C_w	=	EPC of COPC in water (mg/L)
K_p	=	permeability coefficient (centimeters per hour [cm/hour])
ET_w	=	time of exposure (hour/day)
CF	=	conversion factor (0.001 liters per cubic centimeter).

K_p values are available for some inorganics (EPA, 2004). A default K_p value of 0.001 cm/hour (EPA, 2004) will be used for those inorganics for which no chemical-specific values were available.

K_p values for organic chemicals vary by several orders of magnitude, largely dependent on lipophilicity, expressed as a function of the octanol/water partition coefficient. Because the stratum corneum (the outer skin layer) is rich in lipid content, it may act as a sink, initially reducing the transport of chemical to the systemic circulation. With continued exposure and the attainment of steady-state conditions, the rate of transfer to the systemic circulation increases. Therefore, different equations are used to estimate DA, depending on whether the exposure time is less or greater than the estimated time to reach steady state. Non-steady-state exposures occur when either the exposure time is relatively brief (e.g., showering, for most chemicals) or when intermittent exposure occurs throughout the day (e.g., wading exposure to surface water or washing of hands). For exposure scenarios under which steady state is not reached for a given organic chemical (τ>exposure time [ET], see below), the following equation is used to calculate DA (EPA, 2004):

$$DA = 2(FA)(K_p)(C_w)(CF)\sqrt{\left(\frac{6\tau(ET_w)}{\pi}\right)} \qquad \text{Eq. 28}$$

where:

DA	=	dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C_w	=	C_{sw} for surface water, C_{gw} for groundwater, = concentration of COPC in water (mg/L)
FA	=	fraction absorbed from the water (unitless)
K_p	=	permeability coefficient (cm/hour)
CF	=	conversion factor (1E-3 L/cm^3)
τ	=	time for concentration of contaminant in stratum corneum to reach steady state per event (hours)
ET_w	=	ET_{sw} for surface water, ET_{gw} for groundwater, = time of contact (hour(s)/day).

In cases where steady state is reached (τ<ET), such as where the duration of a bath exceeds the time to reach steady state for a given organic compound, the following equation is used to calculate DA (EPA, 2004a):

Eq. 29

$$DA = (FA)(K_p)(C_w)(CF)\left[\frac{ET_w}{1+B} + 2\tau\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

where:

DA	=	dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C_w	=	C_{sw} for surface water, C_{gw} for groundwater, = concentration of COPC in water (mg/L)
FA	=	fraction absorbed from the water (unitless)
K_p	=	permeability coefficient (cm/hour)
CF	=	conversion factor (1E-3 L/cm^3)
τ	=	time for concentration of contaminant in stratum corneum to reach steady state per event (hours)
ET_w	=	ET_{sw} for surface water, ET_{gw} for groundwater, = time of contact (hour(s)/day)
B	=	Ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (unitless).

Assuming one exposure event/day allows expressing ET as hour(s)/day, which preserves the dimensional integrity of the equation.

Where values for τ are not available, they will be calculated as follows (EPA, 2004). Values of K_p and τ to be used in the BHHRA will be appended.

$$\tau = 0.105 \times 10^{(0.0056 \times MW)} \qquad \text{Eq. 30}$$

where:

τ = time for concentration of contaminant in stratum corneum to reach steady state (hours, calculated)
MW = molecular weight.

4.3.4.10 Inhalation of Air Containing VOCs from Groundwater

The following equation is used to estimate the inhaled dose of groundwater VOCs from air during showering:

$$I_{wa} = \frac{(C_{wa})(IR_a)(FI_{wa})(ET_{wa})(EF)(ED)}{(BW)(AT_n)} \qquad \text{Eq. 31}$$

where:

I_{wa} = inhaled dose of COPC (mg/kg-day, calculated)
C_{wa} = EPC of volatile COPC in air from volatilization (mg/m^3)
IR_a = inhalation rate (m^3/hour)
FI_{wa} = fraction of exposure attributed to contaminated medium (unitless)
ET_{wa} = exposure time to VOCs in air (hours/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT_n = averaging time for noncancer (days).

4.4 Toxicity Assessment

Toxicity is defined as the ability of a chemical to induce adverse effects in biological systems. The purpose of the toxicity assessment is two-fold:

- Identify the cancer and noncancer effects that may arise from exposure of humans to the COPCs (hazard assessment).
- Provide an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects (dose-response assessment).

The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described in the following subsection.

4.4.1 Evaluation of Carcinogenic Effects

A few chemicals are known to be human carcinogens, and many more are suspected to be human carcinogens. The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (EPA, 1986). The qualitative aspect is a weight-of-evidence evaluation of the likelihood that a chemical might induce cancer in humans. EPA (1986) recognizes six weight-of-evidence group classifications for carcinogenicity:

- ***Group A - Human Carcinogen.*** Human data are sufficient to identify the chemical as a human carcinogen.
- ***Group B1 - Probable Human Carcinogen.*** Human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.
- ***Group B2 - Probable Human Carcinogen.*** Human data are insufficient to support a causal association, but testing data in animals support a causal association.
- ***Group C - Possible Human Carcinogen.*** Human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.
- ***Group D - Not Classifiable as to Human Carcinogenicity.*** Human and animal data are lacking or inadequate.
- ***Group E - Evidence of Noncarcinogenicity to Humans.*** Human data are negative or lacking, and adequate animal data indicate no association with cancer.

The toxicity value for carcinogenicity, called a cancer slope factor (SF) or cancer unit risk factor (URF), is an estimate of potency. Potency estimates are developed only for chemicals in Groups A, B1, B2, and C, and only if the data are sufficient. The potency estimates are statistically derived from the dose-response curve from the best human or animal study or studies of the chemical. Although human data are often considered to be more reliable than animal data because there is no need to extrapolate the results obtained in one species to another, most human studies have one or more of the following limitations:

- The duration of exposure is usually considerably less than lifetime.
- The concentration or dose of chemical to which the humans were exposed can be only crudely approximated, usually from historical data.
- Concurrent exposure to other chemicals frequently confounds interpretation.

- Data regarding other factors (tobacco, alcohol, illicit or medicinal drug use, nutritional factors and dietary habits, heredity) are usually insufficient to eliminate confounding or quantify its effect on the results.

- Most epidemiologic studies are occupational investigations of workers, which may not accurately reflect the range of sensitivities of the general population.

- Most epidemiologic studies lack the statistical power (i.e., sample size) to detect a low, but chemical-related increased incidence of tumors.

Most potency estimates are derived from animal data, which present different limitations:

- It is necessary to extrapolate from results in animals to predict results in humans, usually done by estimating an equivalent human dose from the animal dose.

- The range of sensitivities arising from genotypic and phenotypic diversity in the human population is not reflected in the animal models ordinarily used in cancer studies.

- Usually very high doses of chemical are used, which may alter normal biology, creating a physiologically artificial state and introducing substantial uncertainty regarding the extrapolation to the low-dose range expected with environmental exposure.

- Individual studies vary in quality (e.g., duration of exposure, group size, scope of evaluation, adequacy of control groups, appropriateness of dose range, absence of concurrent disease, sufficient long-term survival to detect tumors with long induction or latency periods).

The SF or URF is usually expressed as "extra risk" per unit dose, i.e., the additional risk above background in a population corrected for background incidence. It is calculated by the expression:

$$(p_{(d)} - p_{(0)}) / (1 - p_{(0)}) \qquad \text{Eq. 32}$$

where:

$p_{(d)}$ = the probability of cancer associated with dose = 1 mg/kg-day
$p_{(0)}$ = the background probability of developing cancer at dose = 0 mg/kg-day.

The SF is expressed as risk per mg/kg-day^{-1}. To be appropriately conservative, the SF is usually the 95 percent upper bound on the slope of the dose-response curve extrapolated from high

(experimental) doses to the low-dose range expected in environmental exposure scenarios. EPA (1986) assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk.

The oral SF is usually derived directly from the experimental dose data, because oral dose is usually expressed as mg/kg-day. When the test chemical is administered in the diet or drinking water, oral dose first must be estimated from data for the concentration of the test chemical in the food or water, food or water intake data, and BW data.

The EPA (2007e) Integrated Risk Information System (IRIS) expresses inhalation cancer potency (URF) as a unit risk based on concentration, or risk per microgram of chemical/m^3 in ambient air. Because cancer risk characterization requires a potency expressed as risk per mg/kg-day, the unit risk must be converted to the mathematical equivalent of an inhalation cancer SF, or risk per unit dose. Since the inhalation unit risk is based on continuous lifetime exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg) the mathematical conversion consists of multiplying the unit risk (per micrograms per cubic meter [$\mu g/m^3$]) by 70 kg and by 1,000 micrograms per milligram, and dividing the result by 20 m^3/day.

The BHHRA will provide cancer toxicity values, sources, and related information in table format.

4.4.2 Evaluation of Noncancer Effects

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (EPA, 1989b) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical; these may differ depending on the duration (acute or chronic) or route (oral or inhalation) of exposure.
- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased).
- Estimation of the threshold dose for the critical effect for each duration of exposure.
- Development of an uncertainty factor (UF); i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of the critical effect, slope of the dose-response curve, and deficiencies in the database, in regard to developing an RfD for human exposure.
- Identification of the target organ(s) for the critical effect for each route of exposure.

These information points are used to derive an exposure route- and duration-specific toxicity value called an RfD, expressed as mg/kg-day, which is considered to be the dose for humans, with uncertainty of an order of magnitude or greater, at which adverse effects are not expected to occur. Mathematically, it is estimated as the ratio of the threshold dose to the UF. For purposes of risk assessment, chronic exposure is defined as equal to or greater than 7 years, i.e., at least 10 percent of expected life span; subchronic exposure is defined as 2 weeks to 7 years. Although the childhood exposure duration is less than 7 years, only chronic toxicity data will be used to evaluate childhood exposure.

IRIS (EPA, 2007e) expresses the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m^3. Because noncancer risk characterization requires a reference value expressed as mg/kg-day, the RfC must be converted to an inhalation RfD. Because the inhalation RfC is based on continuous exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the RfC (mg/m^3) by 20 m^3/day and dividing the result by 70 kg.

RfD and RfC values are derived for both chronic and subchronic exposure. Under the assumption of monotonicity (incidence, intensity, or severity of effects can increase, but cannot decrease, with increasing magnitude or duration of exposure), a chronic RfD may be considered sufficiently protective for subchronic exposure, but a subchronic RfD may not be protective for chronic exposure. Currently, subchronic RfD values exist for few chemicals. Subchronic RfD values can be derived from chronic RfD values as follows:

- If the UF applied in the derivation of the chronic RfD does not provide for expansion from subchronic to chronic exposure (e.g., if the chronic RfD was derived from a chronic study), the chronic RfD is adopted as being sufficiently protective for subchronic exposure.

- If the UF applied in the derivation of the chronic RfD contains a component to expand from subchronic to chronic exposure, the subchronic RfD is derived by multiplying the chronic RfD by the factor used to expand from subchronic to chronic exposure (e.g., if a factor of 10 was used to expand from subchronic to chronic exposure, the subchronic RfD will be 10 times larger than the chronic RfD).

The BHHRA will provide oral and dermal (discussed in Section 4.4.3) RfDs, RfCs, inhalation RfDs, and related information in table format.

4.4.3 Dermal Toxicity Values

Dermal RfDs and SFs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (GAF), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the GAF. The oral SF is divided, rather than multiplied, by the GAF because the SF is expressed as a reciprocal dose.

4.4.4 Target Organ Toxicity

As a matter of science policy, EPA assumes dose and effect to be additive for noncarcinogenic effects (EPA, 1989a). This assumption provides the justification for adding the hazard quotients (HQ) or HIs in the risk characterization for noncancer effects (Section 4.5.2) resulting from exposure to multiple chemicals, pathways, or media. However, EPA (1989a) acknowledges that adding all HQ or HI values may overestimate hazard, because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism.

Mechanisms of toxicity data sufficient for predicting additivity with a high level of confidence are available for very few chemicals. In the absence of such data, EPA (1989a) assumes that chemicals that act on the same target organ may do so by the same mechanism of toxicity; that is, the target organ serves as a surrogate for mechanism of toxicity. When total HI for all media for a receptor exceeds 1 due to the contributions of several chemicals, it is appropriate to segregate the chemicals by route of exposure and mechanism of toxicity (i.e., target organ) and estimate separate HI values for each target organ.

As a practical matter, because human environmental exposures are likely to involve near- or sub-threshold doses, the target organ chosen for a given chemical is the one associated with the critical effect. If more than one organ is affected by a given chemical at the threshold, then the affected target organs are selected for this chemical. The target organ is also selected on the basis of duration of exposure (i.e., the target organ for chronic or subchronic exposure to low or moderate doses is selected rather than the target organ for acute exposure to high doses) and route of exposure. Because dermal RfD values are derived from oral RfD values, the oral target organ is adopted as the dermal target organ. For some chemicals, no target organ is identified. This occurs when no adverse effects are observed or when adverse effects such as reduced

longevity or growth rate are not accompanied by recognized organ- or system-specific functional or morphologic alteration. Target organs for the oral and inhalation pathway will be provided in the BHHRA.

4.4.5 Sources of Toxicity Information Used in the Risk Assessment

Toxicity values will be selected for use in the BHHRA based on the EPA Office of Solid Waste and Emergency Response Directive 9285.7-53 (EPA, 2003), which prescribes the following hierarchy:

- ***Tier 1*** values: IRIS (EPA, 2007e) database.
- ***Tier 2*** values: EPA's provisional peer-reviewed toxicity values. The provisional peer-reviewed toxicity values are developed by the Office of Research and Development, the National Center for Environmental Assessment, and the Superfund Health Risk Technical Support Center on a chemical-specific basis when requested by the Superfund program.
- ***Tier 3*** values: Other toxicity values from additional EPA and non-EPA sources of toxicity information. As stated in the EPA Office of Solid Waste and Emergency Response directive, "priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed." Two common examples of Tier 3 values are the EPA's Health Effects Assessment Summary Tables (EPA, 1997b) and the California Environmental Protection Agency (2005) Office of Environmental Health Hazard Assessment Toxicity Criteria Database.

GAFs, used to derive dermal RfD values and SFs from the corresponding oral toxicity values, are obtained from the following sources:

- Oral absorption efficiency data compiled by the National Center for Environmental Assessment for the Superfund Health Risk Technical Support Center of EPA.
- Federal agency reviews of the empirical data, such as Agency for Toxic Substances and Disease Registry Toxicological Profiles and various EPA criteria documents.
- Other published reviews of the empirical data.
- The primary literature.

GAFs obtained from reviews are compared to empirical (especially more recent) data, when possible, and are evaluated for suitability for use for deriving dermal toxicity values from oral toxicity values. The suitability of the GAF increases when the following similarities are present

in the oral pharmacokinetic study from which the GAF is derived and in the key toxicity study from which the oral toxicity value is derived:

- The same strain, sex, age, and species of test animal were used.
- The same chemical form (e.g., the same salt or complex of an inorganic element or organic compound) was used.
- The same mode of administration (e.g., diet, drinking water, or gavage vehicle) was used.
- Similar dose rates were used.

The most defensible GAF for each chemical will be used in the BHHRA.

4.4.6 Toxicological Profiles

Toxicological profiles will be developed for all chemicals identified as COPCs. The profile will include data such as the general use of the chemical, synonyms, Chemical Abstracts Services number, chemical-specific physical characteristics, and current and available toxicological and toxicokinetic information (RfDs/RfCs, SFs/URFs, and GAFs).

4.5 Risk Characterization

Risk characterization is the process of applying numerical methods and professional judgment to determine the potential for adverse human health effects to result from the presence of site-specific contaminants. This is done by combining the intake rates estimated during the exposure assessment with the appropriate toxicity information identified during the toxicity assessment. Noncancer hazards and cancer risks are characterized separately.

Quantitative expressions are calculated during risk characterization that describe the probability of developing cancer (ILCRs) or the nonprobabilistic comparison of estimated dose with an RfD for noncancer effects (HQs and HIs). Quantitative estimates are developed for individual chemicals, exposure pathways, and exposure media for each receptor. These quantitative risk characterization expressions, in combination with qualitative information, are used to guide risk management decisions. Risk characterization, as described in this section, is applied only to COPCs.

Generally, the risk characterization follows the methodology prescribed by EPA (1989a), as modified by more recent information and guidance. EPA methods are, appropriately, designed to

be health protective and tend to overestimate, rather than underestimate, risk. The risk results, however, may be overly conservative, because risk characterization involves multiplication of the conservative assumptions built into the estimation of source-term concentrations and EPCs, the exposure (intake) estimates, and the toxicity dose-response assessments.

4.5.1 Carcinogenic Effects of Chemicals

The risk from exposure to potential chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime (the ILCR). In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (EPA, 1989a):

$$ILCR = (CDI)(SF) \qquad \text{Eq. 33}$$

where:

ILCR	=	incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated
CDI	=	chronic daily intake, averaged over 70 years (mg/kg-day)
SF	=	cancer slope factor (per mg/kg-day).

The CDI term in Equation 33 is equivalent to the "I" or "DAD" terms (intake or dose) in the exposure assessment equations (Section 4.3), when these equations are evaluated for cancer intakes/doses.

The use of Equation 33 assumes that chemical carcinogenesis does not exhibit a threshold and that the dose-response relationship is linear in the low-dose range. Because this equation could generate theoretical cancer risks greater than 1 for high dose levels, it is considered to be inaccurate at cancer risks greater than 1E-2. In these cases, cancer risk is estimated by the one-hit model:

$$ILCR = 1 - e^{[(CDI)(SF)]} \qquad \text{Eq. 34}$$

where:

ILCR	=	incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated
$-e^{(CDI)(SF)}$	=	the exponential of the negative of the risk calculated using Equation 33.

As a matter of policy, EPA (1986) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemical's mechanisms of toxicity or sites (organs of the body) of action. Cancer risk arising from simultaneous exposure by a given pathway to multiple chemicals is estimated from the following equation:

$$ILCR_p = ILCR_{(chem\ 1)} + ILCR_{(chem\ 2)} + \cdots ILCR_{(chem\ i)} \qquad \text{Eq. 35}$$

where:

$ILCR_p$ = total pathway incremental lifetime cancer risk, calculated
$ILCR(chem_i)$ = individual chemical cancer risk.

Cancer risk for a given receptor across pathways and across media is summed in the same manner. The sum of the ILCRs summed across pathways is the total ILCR as shown in the equation below:

$$Total\ ILCR = ILCR_{(p\ 1)} + ILCR_{(p\ 2)} + \cdots ILCR_{(p\ i)} \qquad \text{Eq. 36}$$

where:

Total ILCR = total incremental lifetime cancer risk across all pathways
$ILCR_{pi}$ = incremental lifetime cancer risks associate with pathway "I."

The total ILCR represents all additional cancer risks posed to a given receptor by contact with contaminants in site environmental media.

Total ILCRs in the range of 1E-6 to 1E-4 are regarded as acceptable (EPA, 1990); this range is hereinafter referred to as the risk management range. Risks less than this range are regarded as negligible.

4.5.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects of chemicals are evaluated by comparing an exposure level or intake with an RfD. The HQ, defined as the ratio of intake to RfD, is estimated as follows (EPA, 1989a):

$$HQ = I\ /\ RfD \qquad \text{Eq. 37}$$

where:

HQ = hazard quotient (unitless, calculated)
I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day)
RfD = reference dose (mg/kg-day).

The I term in Equation 37 is equivalent to the "I" or "DAD" terms (intake or dose) in the exposure assessment equations (Section 4.3) when these equations are evaluated for noncancer intakes/doses.

As shown above, both the “I” and the RfD are in units of mg/kg-day. The RfD has been developed to represent a dose rate unlikely to result in any adverse noncancer health effects, even to the most susceptible members of the population. Therefore, if the “I” is equal to or less than the RfD (i.e., HQ≤1), adverse noncancer health effects are unlikely. HQ values exceeding 1 do not indicate that noncancer hazard is likely to occur, but rather that the occurrence of an adverse noncancer health effect cannot be termed “unlikely.” The HQ does not define a particular risk level, nor can it be used to infer information regarding a dose-response curve. That is, an HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than the RfD. This approach is different from the probabilistic approach described in Section 4.5.1 to evaluate cancer risks.

In the case of simultaneous exposure of a receptor to several chemicals, an HI is calculated as the sum of the HQs as follows:

$$HI = I_1 / RfD_1 + I_2 / RfD_2 + \ldots I_i / RfD_i \qquad \text{Eq. 38}$$

where:

HI = hazard index (unitless, calculated)
I_i = intake for the ith toxicant
RfD_i = reference dose for the ith toxicant.

If the HI for a given pathway exceeds 1, individual HI values may be calculated for each target organ. A total HI is calculated by summing the HI values, associated by target organ(s), across exposure pathways as follows:

$$Total\, HI_a = HI_{p1-a} + HI_{p2-a} + \ldots HI_{pi-a} \qquad \text{Eq. 39}$$

where:

Total HI_a = total hazard index for target organ "*a*" (unitless, calculated)
$HI_{pi\text{-}a}$ = hazard index for target organ "*a*" via pathway "*i*."

4.5.3 Risk Characterization Results

Risk characterization results for Landfill Areas 1 and 2 will be presented in tables and discussed in text. Potential cancer (Section 4.5.1) and adverse noncancer effects (Section 4.5.2) for each receptor will be presented separately. Detailed spreadsheet calculations will be appended to the BHHRA.

4.6 Uncertainties Analysis

The primary objective of the BHHRA is to characterize and quantify potential human health risks. However, these risks are estimated using incomplete and imperfect information that introduces uncertainties at various stages of the risk assessment process. Uncertainties associated with earlier stages of the risk assessment become magnified when they are concatenated with other uncertainties in the latter stages. Reliance on a simplified numerical presentation of dose rate and risk without consideration of uncertainties, limitations, and assumptions inherent in their derivation can be misleading. For example, the calculated ILCR for a given scenario "A" may be 5E-5 (within the risk management range) and that of scenario "B" given as 5E-4 (exceeding the risk management range). However, if the uncertainties associated with scenario "B" span, for instance, orders of magnitude and the ILCR is regarded as biased high, it is not unlikely that scenario "A" actually presents a higher risk of developing cancer.

The chief goal of this analysis is to evaluate uncertainties and present them in context of their potential impact on the interpretation of the risk assessment results and the types of environmental management decisions that may be based on these results. The uncertainty analysis does not exhaustively describe all potential uncertainties but presents those that have the largest implications for the interpretation of the risk assessment results. This analysis also overviews the types and, as applicable, the magnitude of the uncertainties at each stage of the risk assessment. Although the BHHRA will include generic uncertainties that are common to the state of human health risk assessment practice (e.g., additivity of health effects in the risk characterization), the overall focus of the uncertainties analysis will be on the set of uncertainties that is peculiar to Landfill Areas 1 and 2.

4.6.1 Types of Uncertainty

Uncertainties in risk assessment are categorized into two general types: 1) variability inherent in the (true) heterogeneity of the data set, measurement precision, and measurement accuracy; and 2) uncertainty that arises from data gaps. Estimates of the degree of variability tend to decrease as the sample size increases. This is because larger data sets are less impacted by individual samples/measurements and typically allow for greater accuracy. Uncertainty that arises from data gaps is addressed by applying models and assumptions. Models are applied because they represent a level of understanding to address certain exposure parameters that are impractical or impossible to measure (e.g., COPC concentrations in air that would result from groundwater use that has not yet occurred —or may never occur—at the site). Assumptions represent an educated estimate to address information that is not available (e.g., additivity of carcinogens).

4.6.2 Sources of Uncertainty

A discussion will be provided that presents an overview of general sources of uncertainty and focuses on those most likely to affect the interpretation of the BHHRA results. These sources may include but are not limited to the following:

- Representativeness of samples
- Laboratory procedures and analytical methods
- Sampling methods
- Adequacy of background data set
- Comparisons to background concentrations
- Land use and groundwater use assumptions
- Routes of exposure
- Exposure assessment values
- Exposure models
- Methods of calculating EPCs
- Toxicity values
- Form or isomer of chemical
- Interactions of multiple contaminants.

The BHHRA will identify and describe the unique set of uncertainties associated with the site. Special attention may be given to those uncertainties that are thought to have the most significant impact on potential risk and/or site management decisions.

4.7 Summary/Conclusions

The BHHRA will include a brief summary/conclusion section that will summarize the results of the risk characterization, with a sufficient level of elucidation addressing the effects that

uncertainties may have on these results. Planned and implemented remedial actions will also be discussed as appropriate. The goal is to present the BHHRA in a context that is most appropriate for the support of environmental decision making.

5.0 Screening-Level Ecological Risk Assessment

SLERAs will be conducted for Landfill Areas 1 and 2. The SLERAs are designed to evaluate potential unacceptable risks to ecological receptors posed by site-related contamination potentially present at two landfills. The SLERAs will be conducted in accordance with the EPA *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA, 1997c), known as the "Process Document," and other supplemental guidance (e.g., EPA [2001]). The SLERA methodology will generally follow the eight-step risk assessment process presented in the Process Document, but with Steps 1 and 2 collapsed and Step 3 modified to reflect the current interpretation of guidance that stipulates that the SLERA incorporates multiple lines of evidence to refine the list of chemicals of potential ecological concern (COPEC) prior to further investigation in a baseline ecological risk assessment (BERA), if needed (Figure 5-1):

- Step 1: Problem formulation (Section 5.2)
- Step 2: Preliminary exposure estimate and risk calculation (Section 5.3)
- Step 3a: COPEC Refinement (Section 5.4).

These steps will be described in greater detail in the remainder of the SLERA work plan.

The two landfills will be evaluated separately.

5.1 Summary of Historical Sampling Results

Historical surface soil, surface water, and sediment samples were collected by E&E in 1997. At Landfill Area 1, all three matrices were analyzed for inorganic analytes, VOCs, SVOCs, and pesticides/PCBs. Additionally, surface soil was analyzed for explosive compounds. Surface soil was the only matrix sampled at Landfill Area 2 and was analyzed for inorganic analytes, VOCs, SVOCs, pesticides/PCBs, and explosive compounds.

5.1.1 Landfill Area 1

Four surface soil samples, one surface water sample, and one sediment sample were analyzed for a suite of chemical compounds.

A total of 21 inorganic analytes were detected in Landfill Area 1 surface soil (see Table 2-7 for detected analytes and concentrations). Four VOCs were detected, including acetone, ethyl benzene, total xylene, and toluene (see Table 2-8 for detected concentrations); however, it should

be noted that all four compounds were detected in only one of four samples, and toluene was the only compound that was not qualified as an estimated concentration (i.e., J-qualified). No SVOCs, pesticides/PCBs, or explosive compounds were detected in surface soil (Table 2-8).

Nine inorganic analytes were detected in Landfill Area 1 surface water (see Table 2-11 for detected analytes and concentrations). No VOCs, SVOCs, or pesticides/PCBs were detected in surface water (Table 2-12).

A total of 19 inorganic analytes were detected in Landfill Area 1 sediment (see Table 2-13 for analytes and concentrations). Toluene and total xylene were the only two VOCs detected in sediment; however, both duplicate samples were J qualified and both original samples were nondetect (Table 2-14). A total of 12 SVOCs were detected. However, 8 of the 12 detections were J qualified (see Table 2-14 for compounds and concentrations). Four pesticides were detected in Landfill Area 1 sediment, and all four were reported as J qualified as well (Table 2-14).

5.1.2 Landfill Area 2

Five surface soil samples were analyzed for a suite of chemical compounds. A total of 21 inorganic analytes were detected in Landfill Area 2 surface soil (see Table 2-9 for detected analytes and their respective concentrations). Both acetone and toluene (VOCs) were detected in one of five samples at estimated concentrations (Table 2-10). No SVOCs were detected in Landfill Area 2 surface soil, and only three pesticides were detected in one of five samples (Table 2-10).

No surface water or sediment samples were collected at Landfill Area 2.

5.2 SLERA Problem Formulation

The goal of the screening-level problem formulation is to develop an ecological site conceptual model for the site that addresses the following:

- The environmental setting
- The contaminants known or suspect of being present at the site
- The presence or absence of contaminant fate or transport mechanisms
- The presence or absence of viable exposure pathways and receptors.

The screening-level problem formulation will provide a detailed description of the site, including historical uses, current habitat descriptions, the potential for the presence or absence for various types of receptors to be present, and a list of chemicals that may be potentially linked to previous

site activities. This information will be incorporated in an initial conceptual site model that will describe the ecological properties of the site and their potential interactions with contaminants. A general description of these chemicals' fate and transport and toxicological properties will be provided. Some of the elements of the problem formulation are described in the following subsections and will be expanded upon in the SLERA based on any additional site-specific information available at that time.

5.2.1 Site Description

A description of each landfill will be compiled from existing site reports, maps (e.g., jurisdictional wetlands determination, defined under criteria administered by USACE, Department of the Army, U.S. Department of Defense), available aerial photographs, communication with appropriate agencies (e.g., U.S. Fish and Wildlife Service, National Heritage Program), and a site visit.

5.2.1.1 Site History

For each landfill, the site history will include information about the events that have led to the current investigation.

5.2.1.2 Site Setting

The site setting of each landfill will include geographical location, accessibility, and its surroundings. Land use (e.g., industrial, business, residential, military, agricultural, and undeveloped) upstream and downstream of the sites will be described, with special note to natural areas such as parks, wildlife refuges, and wetlands. A general description of topography, including a description of whether the site is open or wooded, flat or hilly, and marshy or dry, will be completed. The setting will describe surface water associated with each site. A description of the aquifer, overlaying strata, and groundwater discharge area will also be included.

5.2.1.3 Ecological Description

For each landfill, ecological descriptions of site habitat (e.g., wetlands, woodlands, grasslands, open fields, ponds, streams) will be provided. Information regarding site-related plants and animals will be provided, including migratory species of animals and species that use the area during only part of their life cycle. Species of special interest, such as game species, federal- or state-listed endangered or threatened species, and species protected under other statutes, will be described. Other relevant information includes geological information such as hydrology, sediment types, and soil types.

A jurisdictional wetland determination will be undertaken for the drainage ditch and sinkhole along the western flank of the Landfill Area 1 as well as for the pond and sinkhole, northeast and north, respectively, of the Landfill Area 2. Following field investigation and appropriate official USACE investigation completion, the investigation documentation will be submitted to USACE for their review and wetland determination, a process typically requiring approximately 60 days. Upon completion of USACE's jurisdictional wetland delineation and determination, sample locations will be reviewed at Landfill Areas 1 and 2 to focus media sampling within potential wetlands.

5.2.2 Ecological Conceptual Site Model

In order to better understand the two landfills with respect to potential contaminant pathways and generic ecological receptors, Figures 5-2 and 5-3 present ecological conceptual site models for Landfill Areas 1 and 2, respectively.

5.2.2.1 Landfill Area 1

Landfill Area 1 is predominantly an open, grassy area, with a patch of sparse shrub/scrub vegetation on the south-central portion of the landfill and a few deciduous trees on the southeast side. The landfill appears to slope from east to west towards the sinkhole. During the site walk performed by Shaw in January 2000, exposed medical waste was observed on the western side, indicating that soil cover may be thinner on that side of the landfill. It was also noted that medical waste was predominantly exposed along cattle trails.

The sinkhole, immediately west of the landfill, is ringed by deciduous vegetation and somewhat dense underbrush. Vegetation at the bottom of the sinkhole is composed of forbs and terrestrial grasses. Medical refuse exists near the bottom of the sinkhole along the eastern side. It is presumed this was buried waste that has been exposed through erosional processes, as there is also medical waste in the wall of the sinkhole near the top. Larger pieces of metallic waste may have been simply pushed over the side of the sinkhole. There is no evidence of any type of aquatic habitat within the sinkhole.

A steeply sloped ditch leading to the sinkhole, situated along the northwest side of the landfill, is entirely canopied by deciduous trees and thick underbrush. The ditch is approximately 4 to 6 feet wide at the base, and the walls are approximately 10 to 15 feet in height. The bed and walls of the ditch show evidence of large volumes of water passing through the ditch. Presumably heavy rains create surges of overland runoff, which is channeled through the ditch and into the

sinkhole. The ditch appears to be eroding into the landfill, as medical waste is exposed on the east wall of the ditch. There are no signs of aquatic habitat within the ditch.

The ecological risk assessment for Landfill Area 1 will likely focus on terrestrial receptors, as there is no evidence of any type of viable aquatic habitat. It is believed that the western ditch and the sinkhole may become inundated with overland runoff due to heavy rain events; however, due to the geological characteristics of the area, this water would seep to groundwater in a short time. Therefore, there would not be enough time for any type of permanent aquatic habitat to be established.

The conceptual site model presents tentative exposure pathways from sediment and surface water to target receptors. These pathways will either be confirmed or discounted as insignificant or improbable in the RI.

5.2.2.2 Landfill Area 2

Landfill Area 2 is presently used in an agricultural capacity. Prior to this use, it was used for grazing cattle. Only the northwest corner of the site is not presently tilled or planted with commercial/subsistence crops. This corner is vegetated with tall grasses. The landfill terrain can be described as very gently rolling hills with the highest point in the northeastern corner. Low points of the landfill are along the western boundary, the southeastern corner, and the north-central boundary.

A drainage ditch runs along the western fence line of the site and, if water were present, it would flow in a northerly direction. The ditch begins abruptly and does not appear to lead to any surface water body, but rather gently spreads out until it blends in with flat earth. Although this ditch appears to be located within the landfill boundary, no refuse material was observed in the ditch. There is no evidence of aquatic biota; therefore, it is presumed only to contain water during storm events.

A pond is located to the northeast of the historical landfill boundary. It appears to be man-made and is surrounded by a barbed wire fence. Through interviews with local field workers during the Shaw site walk in January 2000, it was learned that the pond is filled by pumping water from a water distribution pipe that runs from a municipal reservoir past the landfill area and into the RAFB. The water is used to irrigate crops via gravity feed. Because the pond is located at the highest point of the area and is fed by an off-site source, it is not expected that potential contaminants from the landfill could migrate via groundwater or surface runoff into the pond

water and/or sediments. Pond surface water and sediment will be sampled as part of this investigation to verify this expectation.

The ecological risk assessment for Landfill Area 2 will focus on terrestrial receptors, as the western ditch could only be considered an aquatic habitat during heavy rain events, and the pond and its associated surface water and sediment are upgradient of the landfill.

The conceptual site model presents tentative exposure pathways from sediment and surface water to target receptors. These pathways will either be confirmed or discounted as insignificant or improbable in the RI.

5.3 Preliminary Exposure Estimate and Risk Calculation

The preliminary exposure estimate and risk calculation will provide an indication as to whether chemicals detected in site media have the potential to result in adverse ecological effects. This will be accomplished by screening the MDC against a conservative screening value. If concentrations exceed the screening value, there is the potential for environmental impacts, and the chemical will be initially retained as a COPEC.

The analytical data to be used will consist of samples collected by Shaw for the RI sampling effort. For these SLERAs, results of surface soil (0 to 1 foot), surface water, and sediment samples (0 to 0.5 foot) will be used. Chapter 3.0 presents details of environmental samples to be collected at each landfill.

As an initial indication of potential ecological risk, the MDCs for each matrix contaminant will be compared individually to appropriate screening values. The screening values used for comparison to detected soil concentrations will be the lowest ecological soil screening levels available among the major receptor groups and guilds for which they were developed (EPA, 2007f). For chemicals that lack ecological soil screening levels, the most recent version of Biological Technical Advisory Group screening values for EPA Region 3 will be used. In cases where no EPA Region 3 screening value is available, other sources (e.g., EPA Region 5, EPA Region 4, Florida Department of Environmental Conservation, etc.) will be used. For sediment and surface water, professional judgment will be used to select the appropriate screening values. If truly aquatic exposures of pelagic and benthic biota are judged to be present, concentrations detected in surface water and sediment will be evaluated using chronic AWQC and appropriate sediment ecotoxicity criteria, respectively. For surface water, the lower of the Puerto Rico or federal chronic AWQC will be used, with site-specific hardness adjustments applied to select inorganic chemicals. For sediment, if the sampled area is sufficiently inundated with water and

consists of depositional fines and solids characteristic of benthic pond or stream substrate, then concentrations will be screened against sediment screening values that are protective of benthic communities following a similar hierarchy as soil (e.g., EPA Region 3 values supplemented with EPA Region 5 and EPA Region 4 values, etc). If the area is judged to be dry for significant periods of time (i.e., only intermittently or sporadically flooded), the sediment will be evaluated as soil and compared with soil screening values as described previously. The comparison will be presented as a ratio described by the following formula:

$$HQ = MDC / SV \qquad \text{Eq. 40}$$

where:

HQ	=	hazard quotient
MDC	=	maximum detected concentration
SV	=	screening value.

Chemicals with HQs less than or equal to 1 will be regarded as having insignificant risk potential to ecological receptors and will be recommended for elimination from further evaluation. In contrast, chemicals with HQs greater than 1 will be defined as COPECs and retained for further evaluation in Step 3a.

Scientific Management Decision Point One. The initial screening step can conclude with a scientific management decision point. At this point, risk managers will examine the information generated from Steps 1 and 2 and declare a necessity to proceed to the next step in the assessment. If, however, the managers conclude that further evaluation is not required, the decision and details of such action will constitute the ecological risk section for the investigative report.

Because ecological benchmark screening values are quite conservative, it is anticipated that several chemicals will produce HQs greater than 1, thus requiring additional examination in the next step.

5.4 Step 3a, COPEC Refinement

Because of the conservative nature of the initial exposure estimate, an additional COPEC refinement step will be used prior to deciding whether further ecological investigation at the site in the form of a BERA is necessary. At the beginning of this activity, COPECs carried from Steps 1 and 2 will undergo a secondary screening evaluation to ensure that subsequent efforts focus on those contaminants from site-related activities that are realistically capable of posing

ecological risk. During COPEC refinement, additional factors will be considered for each chemical that exceeded its screening value, such as the following:

- Is the chemical an essential nutrient?
- Is the chemical naturally occurring, or present at ambient environmental levels?
- Was the chemical detected only sporadically?

If the answer to any of these questions is "yes," then there is reduced concern for the ecological risk associated with that chemical. The COPEC refinement process will result in a list of chemicals that may realistically pose a threat to the environment.

5.4.1 Nutrient Evaluation

Some naturally occurring analytes, such as calcium, magnesium, potassium, and sodium, are nutritionally essential to most organisms and should be excluded from further consideration. Unless the essential nutrient is present at extraordinarily high concentrations (e.g., 10 times greater than its screening value), such chemicals will not be evaluated further.

5.4.2 Background Evaluation

A background evaluation will be conducted on metals and polynuclear aromatic hydrocarbons (PAH) detected in soil at the RAFB to determine whether they are naturally occurring and/or present at ambient levels as the result of typical anthropogenic processes in the area (e.g., PAH deposition resulting from fossil fuel emissions). The background evaluation will be performed according to the methodology outlined in the *Installation-Wide Background Soil Study Report* (Shaw, 2004). According to this methodology, the MDCs for both metals and PAHs will be compared with the UTLs of background concentrations in surface soil to identify the presence of potential hot spots. Further, a statistical comparison between on-site and background data will be conducted using the Wilcoxon Rank Sum test, which is a nonparametric test that compares the medians between two sets of data and provides a determination as to whether they are from the same population. Box plots will also be developed and used to visually compare the site and background distributions and to properly interpret the results of the Wilcoxon Rank Sum test. For metals that fail one or both of these tests, an additional geochemical evaluation will be performed to determine if the elevated concentrations are caused by natural processes (PAHs cannot be evaluated using the geochemical approach). Chemicals determined to be background related will not be recommended for further evaluation in a BERA.

Two sediment/surface water samples will also be collected from the drainage ditches that feed into the sinkhole. These samples will be analyzed for VOCs, SVOCs, TPH-GRO, TPH-DRO, TAL metals, pesticides, and PCBs. The results of these samples will be used to help determine if

any potential contaminants detected in the sinkhole are site related or associated with upgradient sources. This evaluation will be performed through a comparison of site HQs and upstream reference HQs. If the results of this comparison indicate that chemicals detected in the sinkhole likely originated from off-site sources, these chemicals will not be recommended for further evaluation in a BERA.

5.4.3 Frequency of Detection

Chemicals that are detected infrequently may be artifacts in the data that may not reflect site-related activity. Generally, those chemicals that are detected in low concentrations (i.e., in less than 5 percent of the samples from a given medium) will not be considered further, unless their presence is expected based on historical information regarding the site. EPA (2001) states that if data set sizes are adequate, it is appropriate to use this practice in refining COPECS. A minimum of 20 samples is needed to make frequency of detection (FOD)-based decisions on eliminating COPECs. Before chemicals are eliminated based on FOD, additional evaluations will be performed to examine the spatial location of each chemical with a low FOD (EPA, 2001). Chemicals with a low overall FOD may still warrant further evaluation if all detected values occur in one location or in association with a known release in one area (e.g., a "hot spot"). Also, for chemicals with low FOD, reporting limits (RL) should be evaluated to ensure that the low FOD did not result from a high incidence of elevated RLs for a specific chemical or class of chemicals. If a chemical with an FOD equal to or less than 5 percent does not appear to be located in an area where a release occurred and was not detected infrequently due to elevated RLs, then it is eliminated during the Step 3a refinement step.

5.4.4 Spatial Evaluation and COPEC Refinement Conclusions

Those contaminants that remain following this initial COPEC refinement evaluation will be discussed in additional detail that considers actual site conditions. The latter component of the COPEC refinement will involve an integration with the problem formulation for the site. Details of the exposure setting are the context within which contamination levels are evaluated and appropriate ecological receptors are evaluated and selected. The overall quality of the habitat at each site will be examined and hypothetical contaminant fate and transport (exposure) pathways will be evaluated for actual site conditions. A spatial evaluation will be conducted to determine to what extent exposure could occur given the areas and types of habitat where COPECs are located.

Therefore, the goal of the COPEC refinement step will be to provide the risk managers with the following:

- A list of site-related contaminants that truly have the potential to adversely impact the ecological systems at the site

- An integration of the final list of COPECs with a detailed description of site characteristics as a framework for evaluating contaminant impact

Scientific Management Decision Point Two. The risk managers may conclude that there is no unacceptable threat to local biotic communities after the COPEC refinement. Therefore, there would be no need for further evaluation, in which case details of the basis for that action will constitute the ecological risk section for the investigative report. Follow-on steps (EPA, 1997c) should be performed for the site only if results indicate all of the following:

- Viable ecological habitat exists for supporting valuable ecological communities of terrestrial and/or aquatic species.

- One or more final COPECs that pose a realistic threat to the environment are present at the site.

- Wildlife species are present in the area, and a reasonable chance exists that ecological receptors regularly utilize the site, resulting in exposure to site media.

The presence of viable ecological habitat will be determined using professional judgment. "Viable habitat" refers to habitat parameters that are essential for regular use of the area by ecological receptors. These parameters include foraging areas, the availability of food and water, a relative lack of human presence, and vegetation or substrate structure that provides shelter or cover for nesting or predator evasion. If these qualities are present at the site such that populations of organisms are likely to regularly use the site for foraging or other purposes, then this criterion is considered to be met.

5.5 Baseline Ecological Risk Assessment

Should the risk managers decide that there are significant ecological threats at either of the landfills, a BERA will be conducted for that/those site(s). Details of those procedures are provided in the Process Document (EPA, 1997c) and include the remaining portions of Steps 3 through 8 as presented on Figure 5-1. Details on how the BERA would be conducted are not provided at this time because new analytical data are not yet available, and the screening-level steps necessary to support the selection of appropriate ecological receptors are not complete. The selection of specific stressors, valid ecological receptors, and clearly identified habitat types will require input from the risk managers.

If a BERA is conducted, a report on the data, results, professional judgment, and conclusions concerning the potential for ecological impacts at the site will be prepared. Risk management actions, which may include proceeding with remedial activities, implementing biological monitoring, or a decision for no further action, are beyond the scope of ecological risk assessment. Risk managers and stakeholders will select the final decision(s) with input from the risk assessors and results of the BERA.

6.0 Site Safety and Health Plan

All work at the site performed by Shaw or its subcontractors will be performed in accordance with the accident prevention plan and site safety and health plan appendix (Shaw, 2006b), which was prepared and submitted by Shaw in August 2006, and the SSHP presented as Appendix B of this WP.

The SSHP complies with applicable Occupational Safety and health Administration (OSHA), EPA, and USACE regulations. This plan follows the guidelines established in the following:

- Standard Operating Safety Guidelines (EPA, November 1984)
- Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (National Institute of Occupational Safety and Health 86-116)
- 29 CFR 1910.120, U.S. Department of Labor/OSHA
- 29 CFR 1926.65, U.S. Department of Labor/OSHA
- Safety and Health Elements for Hazardous Toxic and Radiologic Waste and OWE Documents (USACE CER 385-1-91, [03 November 2003])

The contents of the SSHP are also consistent with Shaw health and safety policies and procedures.

7.0 Project Organization

The primary participants involved in executing this investigation include the USACE-Savannah District, Shaw, and Shaw's approved subcontractors. A project organization chart is presented on Figure 7-1.

7.1 USACE Personnel

Project Manager. The USACE PM is responsible for programming and securing funding for environmental restoration activities while ensuring the work to be performed is formerly used defense site-eligible. The PM is fiscally responsible for the project and is therefore consulted on matters involving funding issues.

Contracting Officer. The contracting officer (CO) is the contractual authority between USACE and Shaw. The CO is the only person with contractual authority to negotiate, enter into contracts, obligate funds, order changes, and negotiate resultant increases or decreases in the estimated contract cost, fee, and performance schedule. The CO is responsible for award and administration of binding contractual documents. Other CO responsibilities include task order award, change notification, negotiation, cost overruns, small and small-disadvantaged business subcontracting, subcontract consent, government property tracking, reporting and dispositions, and project closeout.

Contracting Officer Representative. The contracting officer representative (COR) is responsible for providing technical direction to Shaw throughout project execution, approving in-scope changes, advising the CO of changes that may affect cost and/or schedule, and issuing technical direction. For this RI of Landfill Areas 1 and 2, a COR is appointed by the USACE-Savannah District. The COR's authority is limited to technical direction within the general scope of work stated in the contract. The COR may not direct work to be done that is outside the contract scope, request a subcontract change, or otherwise cause an increase or decrease in estimated subcontract cost, fee, or performance schedule without written concurrence from the CO.

Technical Manager. The USACE technical manager (TM) serves as the primary focal point for all project issues relative to the work at the RAFB. The USACE TM facilitates the implementation of the terms and conditions of the delivery orders, including interpreting specifications, drawings, or other technical portions of the work description; coordinating

responses to technical questions; and reviewing and recommending approval of technical reports and other deliverable submitted by Shaw. The USACE TM provides the QA for the RI of Landfill Areas 1 and 2.

7.2 Shaw Personnel

Shaw management and technical personnel for this project include the following:

- ***Project Manager, Ken Cunningham, PG.*** The PM is Shaw's representative responsible for the effective execution of this project and serves as Shaw's primary focal point for all environmental restoration activities at the RAFB, both with USACE and within Shaw. The PM takes direction from the USACE COR in executing the RI work plan.

- ***Health and Safety Manager, Doug Russell.*** The health and safety manager for this project developed the SSHP referenced in this work plan. This plan complies with 29 CFR Part 1910.120 and 29 CFR 1926.65 in all aspects and includes medical surveillance and training requirements, hazard assessment, personal protective equipment specifications, field implementation procedures, and audits. The health and safety manager is the contact for regulatory agencies on matters of safety and health.

- ***Investigative Task Manager, Zach Parham.*** The task leader coordinates the effective execution of the field activities, including preparing work plans, conducting the field activities, and preparing the final construction report. The task leader will coordinate closely with the site manager and data management group during execution of the field activities to ensure completion in accordance with the work plans.

- ***Project Chemist, Joyce Dishner-McGee.*** The project chemist will work with the project management team in formulating plans and approaches. The project chemist will assess sampling, analytical, and QC requirements for each project task and assist in the interpretation and use of sampling and QC data. The project chemist will review field, analytical, and QC data and prepare a QC summary report before those data are transferred to permanent storage or reported to other project participants.

- ***Site Manager, Chris Patrick.*** The site manager provides management and technical direction of tasks. The site manager assigns and directs all on-site activities, ensures adherence to project plans, and prepares status reports for the PM. The site manager also manages subcontractor activities and implements the health and safety program.

- ***Human Health Risk Assessor, Tom Siard.*** The human health risk assessor will formulate the work scope of the human health portion of the risk assessment. This will ensure that all potential current and future exposure scenarios are considered.

The human health risk assessor will also review pertinent data as they are received and help prepare the risk assessment report.

- ***Ecological Risk Assessor, Jon Lindberg.*** The ecological risk assessor will determine the work scope of the ecological portion of the risk assessment. The ecological risk assessor will review field data as they are received and help prepare the risk assessment report.

8.0 Schedule

To manage all phases of the project effectively, the PM will utilize the Shaw Project Management System. The integrated project planning, tracking, and control system is composed of two primary concepts:

- Versatile, Integrated System for Shaw's Operational Needs is used to track and maintain information on project expenses on a weekly basis.
- Schedule and budget controls: Shaw uses Primavera Project Planner as a planning system to integrate schedule, resource allocation, and budget.

The schedule for preparing the RI work plan and performing the investigation at Landfill Areas 1 and 2 will be prepared upon approval of the WP by EQB. The PM will actively manage the schedule and internal checks will determine the problems early, eliminating costly delays and rework that could impact critical schedule milestones.

9.0 References

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TABLES

Table 2-1

Monitoring Well Construction Details for Landfill Area 1
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Well Number	Total Depth in Feet (bgs)	Screened Interval in Feet (bgs)	Top of Casing Elevation (above msl)	July 1997 Results			December 1998 Results			Well Diameter and Surface Protection
				Depth to Water Below Top of Casing (in feet)	Water Table Elevation (above msl)	Depth to Water in Feet (bgs)	Depth to Water Below Top of Casing (in feet)	Water Table Elevation (above msl)	Depth to Water in Feet (bgs)	
RMW1-1	277	238 - 273	247.14	242.01	5.13	239.36	241.80	5.34	239.15	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW1-2	257	229 - 244	241.50	236.18	5.32	233.39	236.01	5.49	233.22	2-inch ID, locking cap, flush-mounted metal cover, concrete pad
RMW1-3	247	210 - 225	222.59	217.38	5.21	214.69	217.20	5.39	214.51	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW1-4	257	222 - 237	231.43	226.16	5.27	226.40	226.01	5.42	226.25	2-inch ID, flush-mounted, locking metal outer case, locking cap, concrete pad

bgs - Below ground surface.
ID - Inside diameter.
msl - Mean sea level.

Table 2-2

Monitoring Well Construction Details for Landfill Area 2
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Well Number	Total Depth in Feet (bgs)	Screened Interval in Feet (bgs)	Top of Casing Elevation (above msl)	July 1997 Results			December 1998 Results			Well Diameter and Surface Protection
				Depth to Water Below Top of Casing (in feet)	Water Table Elevation (above msl)	Depth to Water in Feet (bgs)	Depth to Water Below Top of Casing (in feet)	Water Table Elevation (above msl)	Depth to Water in Feet (bgs)	
RMW2-1	247	220 - 235	231.74	225.96	5.78	223.49	225.68	6.06	223.21	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW2-2	247	205 - 220	219.36	213.70	5.66	210.84	213.49	5.90	210.63	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW2-3	247	215 - 230	227.25	221.69	5.56	219.11	221.44	5.81	218.86	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW2-4	257	216 - 231	228.46	223.34	5.12	221.34	223.13	5.37	221.13	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards
RMW2-5	247	211 - 226	221.93	218.86	3.07	215.91	218.56	3.34	215.61	2-inch ID, locking metal outer case, locking cap, concrete pad, bumper guards

bgs - Below ground surface.
ID - Inside diameter.
msl - Mean sea level.

Table 2-3

Inorganic Groundwater Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc., in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location				Puerto Rico Groundwater Quality Standards (µg/L)	EPA Region 3 RBCs (Tapwater µg/L)	EPA MCLs (Drinking Water (µg/L)
	RMW1-1 (µg/L)	RMW1-2 (µg/L)	RMW1-3 (µg/L)	RMW1-4 (µg/L)			
June 1997							
Lead	ND	ND	5.8	ND (ND)	50	NE	NE
Selenium	5.4	ND	ND	ND (ND)	NE	180	50
Zinc	15	ND		ND (ND)	NE	11,000	5,000[a]
Manganese	26	ND	11	ND (ND)	NE	730	50[a]
Iron	**450**	ND	79	120 (110)	NE	11,000	300[a]
Chromium total	16	ND	ND	ND (ND)	NE	110	100
Calcium	100,000	94,000	100,000	100,000 (80,000)	NE	NE	NE
Magnesium	12,000	14,000	15,000	16,000 (13,000)	NE	NE	NE
Aluminum	150	ND	ND	ND (ND)	NE	37,000	200[a]
Sodium	33,000	46,000	60,000	73,000 (56,000)	NE	NE	NE
Potassium	1,300	3,700	3,300	4,200 (3,200)	NE	NE	NE
December 1998							
Manganese	17	ND	ND	ND (ND)	NE	730	50[a]
Iron	ND	180	62	ND	NE	11,000	300[a]
Calcium	140,000	100,000	100,000	110,000 (96,000)	NE	NE	NE
Magnesium	14,000	12,000	16,000	18,000 (16,000)	NE	NE	NE
Barium	74	ND	ND	ND	NE	2,600	2,000
Aluminum	160	ND	ND	ND	NE	37,000	200[a]
Sodium	53,000	39,000	65,000	79,000 (72,000)	NE	NE	NE
Potassium	4,000	3,000	2,900	34,000 (3,000)	NE	NE	NE

[a] Secondary standard.
EPA - U.S. Environmental Protection Agency.
MCL - Maximum contaminant level.
µg/L - Micrograms per liter.

ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
RBC - Risk-based concentration.
450 - Bolded, shaded value exceeds EPA MCL.

Table 2-4

Organic Groundwater Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location				Puerto Rico Water Quality Standards (µg/L)	EPA Region 3 RBCs (Tapwater µg/L)	EPA MCLs Drinking Water (µg/L)
	RMW1-1 (µg/L)	RMW1-2 (µg/L)	RMW1-3 (µg/L)	RMW1-4 (µg/L)			
June 1997							
VOCs							
Acetone	5.0 JB	ND	ND	ND (ND)	NE	3,700	NE
Carbon disulfide	11 B	ND	ND	ND (ND)	NE	1,000	NE
Chloroform	ND	ND	ND	**3.4 J (3.1 J)**	NE	0.150	100
Trichloroethylene	1.2 J	**2.2 J**	**4.8 J**	**7.7 (7.8)**	5.0	1.60	5.0
BNAs	ND	ND	ND	ND (ND)	NE	Various	Various
Pesticides/PCBs	ND	ND	ND	ND (ND)	Various	Various	Various
TPH as diesel	ND	120	ND	ND (ND)	NE	NE	NE
TPH as gasoline	ND	ND	ND	ND (ND)	NE	NE	NE
December 1998							
VOCs							
Acetone	2.0 J	ND	ND	ND (ND)	NE	3,700	NE
Trichloroethene	1.6 J	**2.3 J**	**8.9**	**8.4 (7.8)**	5.0	1.60	5.0
BNAs							
bis(2-Ethylhexyl)phthalate	ND	ND	ND	ND (ND)	NE	4.8	NE
Pesticides/PCBs							
Aroclor 1260	ND	ND	**0.48 J**	ND (ND)	NE	0.033	0.0005
TPH as diesel	220	ND	ND	ND (ND)	NE	NE	NE
TPH as gasoline	ND	ND	ND	62 JB (57 JB)	NE	NE	NE

µg/L - Micrograms per liter.
B - Analyte present in field or lab blank sample.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
MCL - Maximum contaminant level.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.
2.2 - Bolded, shaded value exceeds either the EPA Region 3 RBC (tap water), the EPA MCL, or the Puerto Rico water quality standard for drinking water.
7.7 (7.8) - Sample result (duplicate sample result).

Table 2-5

Inorganic Groundwater Analytical Results from Landfill Area 2 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location					Puerto Rico Groundwater Quality Standards (µg/L)	EPA Region 3 RBCs (Tapwater µg/L)	EPA MCLs Drinking Water (µg/L)
	RMW2-1 (µg/L)	RMW2-2 (µg/L)	RMW2-3 (µg/L)	RMW2-4 (µg/L)	RMW2-5 (µg/L)			
June 1997								
Lead	8.5	ND	9.8	ND	ND (ND)	50	NE	NE
Selenium	6.0	ND	6.6	ND	ND (ND)	NE	180	50
Zinc	23	23	16	ND	ND (ND)	NE	11,000	5,000[a]
Manganese	**97**	ND	10	ND	ND (ND)	NE	730	50[a]
Iron	**540 J**	**330 J**	**490 J**	ND	ND (ND)	NE	11,000	300[a]
Calcium	100,000	130,000	150,000	80,000	80,000 (85,000)	NE	NE	NE
Magnesium	13,000	9,100	18,000	17,000	16,000 (18,000)	NE	NE	NE
Aluminum	**420**	180	160	ND	ND (ND)	NE	37,000	200[a]
Barium	46	ND	24	ND	ND (ND)	NE	2,600	2,000
Sodium	99,000	24,000	87,000	83,000	75,000 (86,000)	NE	NE	NE
Potassium	3,200	1,300	4,200	3,800	3,200 (4,300)	NE	NE	NE
December 1998								
Lead	ND (10)	ND	ND	ND	ND	50	NE	NE
Zinc	ND (15)	ND	ND	ND	ND	NE	11,000	5,000[a]
Nickel	ND (ND)	ND	49	ND	ND	NE	730	100
Manganese	**71**	ND	ND	ND	ND	NE	730	50[a]
Iron	120 **(780)**	**530**	**390**	74	ND	NE	11,000	300[a]
Calcium	90,000 (108,000)	150,000	150,000	87,000	93,000	NE	NE	NE
Magnesium	18,700 (17,900)	10,000	18,000	19,000	19,000	NE	NE	NE
Aluminum	ND (21)	ND	ND	ND	ND	NE	2,600	2,000
Barium	ND **(630)**	**480**	**290**	ND	ND	NE	37,000	200[a]
Sodium	89,200 (85,700)	22,000	83,000	88,000	91,000	NE	NE	NE
Potassium	3,800 (4,190_)	ND	3,400	4,100	3,800	NE	NE	NE

[a] Secondary standard.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
µg/L - Micrograms per liter.
MCL - Maximum contaminant level.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
RBC - Risk-based concentration.
97 - Bolded, shaded value exceeds EPA MCL.

Table 2-6

Organic Groundwater Analytical Results from Landfill Area 2 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location					Puerto Rico Groundwater Quality Standards (µg/L)	EPA Region 3 RBCs (Tapwater µg/L)	EPA MCLs Drinking Water (µg/L)
	RMW2-1 (µg/L)	RMW2-2 (µg/L)	RMW2-3 (µg/L)	RMW2-4 (µg/L)	RMW2-5 (µg/L)			
VOCs								
Chloroform	**4.7 J**	ND	**3.1 J**	ND	ND (ND)	NE	0.150	100
Bromodichloromethane	**1.2 J**	ND	ND	ND	ND (ND)	NE	0.170	100
Trichloroethylene	1.2 J	ND	1.6 J	1.1 J	1.2 J (1.2 J)	200	1.60	5.0
BNAs	ND	ND	ND	ND	ND (ND)	NE	Various	Various
Pesticides/PCBs	ND	ND	ND	ND	ND (ND)	Various	Various	Various
TPH as diesel	ND	ND	ND	ND	ND (ND)	NE	NE	NE
TPH as gasoline	ND	ND	ND	ND	ND (ND)	NE	NE	NE
December 1998								
VOCs								
Trichloroethene	1.5 J (1.2 J)	ND	1.5 J	1.2 J	1.4 J	200	1.60	5.0
BNAs	ND (ND)	ND	ND	ND	ND (ND)	NE	Various	Various
Pesticides/PCBs	ND (ND)	ND	ND	ND	ND (ND)	Various	Various	Various
TPH as diesel	ND (ND)	ND	ND	ND	ND (ND)	NE	NE	NE
TPH as gasoline	ND (ND)	ND	ND	ND	ND (ND)	NE	NE	NE

BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
µg/L - Micrograms per liter.
MCL - Maximum contaminant level.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.
4.7 - Bolded, shaded value exceeds either the EPA Region III RBC (tap water), the EPA MCL, or the Puerto Rico water quality standard for drinking water.

Table 2-7

Inorganic Surface Soil Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location				EPA Region 3 Residential RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	RMW1-1 (0-2.0 ft bgs) mg/kg	RMW1-2 (0-2.0 ft bgs) mg/kg	RMW1-3 (0-2.0 ft bgs) mg/kg	RMW1-4 (0-2.0 ft bgs) mg/kg		
Arsenic	**14** [RBC]	**35 (38)** [RBC,SSL]	**27** [RBC]	**39** [RBC,SSL]	0.43	29
Lead	7.8	11 J (11 J)	26 J	6.4	400 [c]	400 c
Selenium	0.84	1.2 (1.3)	0.66	ND	390	5
Thallium	ND	**0.81 (1.2)** [SSL]	**0.93** [SSL]	**2.4** [SSL]	5.5	0.7
Aluminum	7,300	15,000 (15,000)	11,000	9,400	78,000	NE
Antimony	**6.8J** [SSL]	ND (ND)	ND	ND	31	5
Barium	16	35 (30)	24	39 J	5,500	1,600
Beryllium	ND	1.1 (1.2)	0.71	0.67	160	63
Calcium	140,000	13,000 (6,400)	180,000	580	NE	NE
Chromium (total)	**73** [SSL]	**160 (180)** [SSL]	**120** [SSL]	**140** [SSL]	230 [d]	38
Cobalt	6.2	15 (16)	7.2	11	4,700	NE
Copper	9.8	18 (19)	13	19	3,100	NE
Iron	20,000	**42,000 (46,000)** [RBC]	**30,000** [RBC]	**45,000** [RBC]	23,000	NE
Magnesium	830	460 (460)	1,000	400	NE	NE
Manganese	410	1,200 (1,100)	450	860	1,600	NE
Nickel	11	28 (30)	17	23	1,600	130
Potassium	260	270 (290)	300	200	NE	NE
Sodium	150	ND (ND)	140	140	NE	NE
Vanadium	46	90 (99)	63	100	550	6,000
Zinc	17	33 (35)	28	25	23,000	12,000
Mercury	ND	0.045 (0.035)	0.069	ND	23 [e]	2

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[d] This value is the RBC for Chromium VI.

[e] This value is the RBC for mercuric chloride.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
EPA - U.S. Environmental Protection Agency.
ft - Feet.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
RCRA - Resource Conservation and Recovery Act.
NE - Not established.
RBC - Risk-based concentration.
SSL - Soil screening level.
35 (38) - Sample results (duplicate sample result).
14 [RBC] - Bolded, shaded value exceeds EPA Region 3 RBC.
39 [SSL] - Bolded, shaded value exceeds EPA Generic SSL.

Table 2-8

Organic Surface Soil Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location				EPA Region 3 Residential RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	RMW1-1 (0-2.0 ft bgs) (mg/kg)	RMW1-2 (0-2.0 ft bgs) (mg/kg)	RMW1-3 (0-2.0 ft bgs) (mg/kg)	RMW1-4 (0-2.0 ft bgs) (mg/kg)		
VOCs						
Acetone	ND	ND (ND)	ND	0.0095 J	7,800	16
Ethyl benzene	ND	ND (ND)	0.0015 J	ND	7,800	13
Total xylenes	ND	ND (ND)	0.0014 J	ND	160,000[c]	190[c]
Toluene	ND	ND (ND)	ND	0.0076	16,000	12
BNAs	ND	ND (ND)	ND	ND	Various	Various
Pesticides/PCBs	ND	ND (ND)	ND	ND	Various	Various
TPH as diesel	ND	ND (ND)	ND	ND	NE	NE
TPH as gasoline	ND	ND (ND)	ND	ND	NE	NE
Explosives	ND	ND (ND)	ND	ND	Various	Various

Note: Puerto Rico has not established soil standards; therefore, soil sample analytical results were compared to EPA Region 3 Risk-Based Concentrations for Residential Soil and EPA Generic Soil Screening Levels as conservative initial screening criteria.

[a] Risk-based concentration from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor) of 20.

[c]These values are the RBC and SSL for ortho-xylene.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
ft - Feet.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-9

Inorganic Surface Soil Analytical Results from Landfill Area 2 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location					EPA Region 3 Residential RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	RMW2-1 (0-2.0 ft bgs)	RMW2-2 (0-2.0 ft bgs)	RMW2-3 (0-2.0 ft bgs)	RMW2-4 (0-2.0 ft bgs)	RMW-2-5 (0-2.0 ft bgs)		
Arsenic	**38** [RBC, SSL]	**38** [RBC,SSL]	**40 (43)** [RBC,SSL]	**43** [RBC,SSL]	**33** [RBC,SSL]	0.43	29
Lead	9.6	9.9	10 (11)	7.0	8.5	400 [c]	400 c
Selenium	2.4	1.8 J	1.1 (2.1)	ND	ND	390	5
Thallium	**2.4** [SSL]	**1.9** [SSL]	**2.2 (2.0)** [SSL]	**1.8** [SSL]	ND	5.5	0.7
Aluminum	16,000	15000	16,000 (19,000)	11,000	12,000	78,000	NE
Barium	55	32	49 (46)	23	26	5,500	1,600
Beryllium	0.60	0.79	0.77 (0.85)	0.77	0.62	160	63
Cadmium	ND	ND	ND (ND)	ND	3.3	39	8
Calcium	1,600	11,000	1,200 (960)	1200	1,300	NE	NE
Chromium (total)	**130 J** [SSL]	**150** [SSL]	**150 J (160) J** [SSL]	**180** [SSL]	**140** [SSL]	230 [d]	38
Cobalt	14	9.2	19 (18)	14	8.5	4,700	NE
Copper	25	19	23 (25)	19	19	3,100	NE
Iron	**41,000** [RBC]	**41,000** [RBC]	**43,000 (47,000)** [RBC]	**47,000** [RBC]	**39,000** [RBC]	23,000	NE
Magnesium	600	560	580 (630)	480	ND	NE	NE
Manganese	1,700	930	**1,800 (1,600)** [RBC]	830	420	1,600	NE
Nickel	20	21	24 (26)	23	19	1,600	130
Potassium	520	320	360 (430)	240	360	NE	NE
Sodium	270	ND	ND (ND)	ND	ND	NE	NE
Vanadium	94	94	97 (100)	100	92	550	6,000
Zinc	60	46	52 (56)	36	36	23,000	12,000
Mercury	0.048	0.034	0.046 (0.059)	0.070	ND	23 [e]	2

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[d] This value is the RBC for Chromium VI.

[e] This value is the RBC for mercuric chloride.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
ft - Feet.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act.
SSL - Soil screening level.
40 (43) - Sample result (duplicate sample result).
38 [RBC] - Bolded, shaded value exceeds EPA Region 3 residential RBC.
38 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-10

Organic Surface Soil Analytical Results from Landfill Area 2 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location					EPA Region 3 Residential RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	RMW2-1 (0-2.0 ft bgs) (mg/kg)	RMW2-2 (0-2.0 ft bgs) (mg/kg)	RMW2-3 (0-2.0 ft bgs) (mg/kg)	RMW2-4 (0-2.0 ft bgs) (mg/kg)	RMW2-5 (0-2.0 ft bgs) (mg/kg)		
VOCs							
Acetone	ND	ND	ND (ND)	0.0058 J	ND	7,800	16
Toluene	ND	0.0018 J	ND (ND)	ND	ND	16,000	12
BNAs	ND	ND	ND (ND)	ND	ND	Various	Various
Pesticides/PCBs							
4,4'-DDD	ND	0.0034	ND (ND)	ND	ND	2.7	16
4,4'-DDE	ND	0.010	ND (ND)	ND	ND	1.9	54
4,4'-DDT	ND	0.0063	ND (ND)	ND	ND	1.9	32
TPH as diesel	ND	ND	ND (ND)	ND	ND	NE	NE
TPH as gasoline	ND	ND	ND (ND)	ND	ND	NE	NE
Explosives	ND	ND	ND (ND)	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor (DAF) of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
ft - Feet.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-11

Inorganic Surface Water Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample R-1-SW-001 (µg/L)	Puerto Rico Surface Water Quality Standards (µg/L)
Lead	6.4 (6.3)	15
Zinc	16 (20)	50
Manganese	16 (16)	50
Iron	1,000 J (1,100 J)	1,000
Calcium	8,400 (7,900)	NE
Magnesium	1,000 (960)	NE
Aluminum	580 (620)	NE
Sodium	1,000 (ND)	NE
Potassium	2,400 (2,200)	NE

J - Estimated concentration.
µg/L - Micrograms per liter.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.

Table 2-12

Organic Surface Water Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample R-1-SW-001 (µg/L)	Puerto Rico Surface Water Quality Standards (µg/L)
VOCs	ND (ND)	Various
BNAs	ND (ND)	NE
Pesticides/PCBs	ND (ND)	Various
TPH as diesel	ND (ND)	NE
TPH as gasoline.	ND (ND)	NE

BNA - Base neutral acid/extractable organic compound.
µg/L - Micrograms per liter.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
PCB - Polychlorinated biphenyl.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-13

Inorganic Sediment Sample Analytical Results from Landfill Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location R-1-SD-001 (mg/kg)	EPA Region 3 RBC[a] (Residential; mg/kg)
Arsenic	**19 (30)**	0.43
Lead	72 J (140 J)	400[b]
Selenium	0.72 (ND)	390
Thallium	ND (1.0)	5.5
Aluminum	11,000 (14,000)	78,000
Barium	27 J (220 J)	5,500
Calcium	200,000 (140,000)	NE
Chromium total	81 (120)	230[c]
Cobalt	4.8 (9.1)	4,700
Copper	28 (52)	3,100
Iron	23,000 J **(57,000 J)**	23,000
Magnesium	1,300 (1,600)	NE
Manganese	320 (510)	1,600
Nickel	15 (24)	1,600
Potassium	540 (1,100)	NE
Sodium	210 (240)	NE
Vanadium	45 (63)	550
Zinc	190 (310)	23,000
Mercury	0.37 (0.41)	23[d]

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).
[c] This value is the RBC for Chromium VI.
[d] This value is the RBC for mercuric oxide.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
RBC - Risk-based concentration.
NE - Not established.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
RCRA - Resource Conservation and Recovery Act.
11,000 (14,000) - Sample result (duplicate sample result).
19 (30) = Bolded, shaded value exceeds EPA Region 3 Residential RBC.

Table 2-14

Organic Sediment Sample Analytical Results from Landfilll Area 1 from Site Investigation Performed by Ecology and Environment, Inc. in June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Location R-1-SD-001 (mg/kg)	EPA Region 3 RBC[a] (Residential; mg/kg)
VOCs		
Toluene	ND (0.0017 J)	16,000
Total xylenes	ND (0.0067 J)	160,000
BNAs		
Phenanthrene	0.23 J (16 J)	NE
Anthracene	0.045 J (ND)	23,000
Fluroanthene	0.56 (0.53)	3,100
Pyrene	0.45 (0.48)	2,300
Benzo(a)anthracene	0.42 J (0.42)	0.87
Chrysene	0.44 (0.47)	870
Benzo(b)fluoranthene	0.64 **(0.94)**	0.87
Benzo(k)fluoranthene	0.32 J (ND)	8.7
Benzo(a)pyrene	**0.40 J (0.41 J)**	0.087
Indeno(1,2,3-cd)pyrene	0.25 J (0.27 J)	0.87
Dibenzo(a,h)anthracene	**0.13 J (0.13 J)**	0.087
Benzo(g,h,i)perylene	0.28 J (0.29 J)	NE
Pesticides/PCBs		
Gamma-chlordane	0.0072 J (0.0074 J)	0.49
4,4'-DDD	0.0089 J (ND)	2.70
4,4'-DDE	0.034 (0.027 J)	1.90
4,4-'DDT	0.039 J (ND)	1.90
TPH as diesel	42 (68)	NE
TPH as gasoline	ND (ND)	NE

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.
0.0018J (0.0027J) - Sample result (duplicate sample) result.
0.94 - Bolded, shaded value exceeds EPA Region 3 Residential RBC.

Table 2-15

Inorganic Subsurface Soil Analytical Results, Monitoring Well RMW1-1, Landfill Area 1, June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	15 - 17 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**19** RBC	**36** RBC,SSL	**29** RBC	3.8	29
Lead	5.7	8.5	10	1,545[c]	400[d]
Selenium	ND	1.0	ND	10,000	5
Thallium	**1.2** SSL	0.63	**1.1** SSL	140	0.7
Aluminum	8,800	11,000	14,000	2,000,000	NE
Barium	30	230	33	140,000	1,600
Beryllium	1.8	1.5	1.7	4,100	63
Calcium	36,000	800	4,200	NE	NE
Chromium total	**150** SSL	**140** SSL	23	610[e]	38
Cobalt	16	21	11	120,000	NE
Copper	17	17	27	82,000	NE
Iron	50,000	47,000	56,000	610,000	NE
Magnesium	560	460	1,400	NE	NE
Manganese	280	1,600	600	41,000	NE
Nickel	17	25	58	41,000	130
Potassium	170	280	460	NE	NE
Vanadium	110	110	110	14,000	6,000
Zinc	23	24	42	610,000	12,000
Mercury	ND	ND	0.038	610[f]	2

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workgroup for an Interim Appraoch to Assessing Risk Associated with Adult Exposures to Lead in Soil*, (EPA, 1996).

[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[e] This value is the RBC for Chromium VI.

[f] This value is the RBC for mercuric chloride.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RCRA - Resource Conservation and Recovery Act.
RBC - Risk-based concentration.
SSL - Soil screening level.
19 RBC - Bolded, shaded value exceeds EPA Region 3 RBC.
36 SSL - Bolded, shaded value exceeds EPA generic SSL.

Table 2-16

Organic Subsurface Soil Analytical Results, Monitoring Well RMW1-1, Landfill Area 1, June 1997 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs)			EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	4 - 6 (mg/kg)	9 - 11 (mg/kg)	15 - 17 (mg/kg)		
VOCs	ND	ND	ND	Various	Various
BNAs	ND	ND	ND	Various	Various
Pesticides/PCBs	ND	ND	ND	Various	Various
TPH as diesel	ND	ND	ND	NE	NE
TPH as gasoline	ND	ND	ND	NE	NE
Explosives	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-17

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW1-4, Landfill Area 1, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	15 - 17 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**66** [RBC,SSL]	**42** [RBC,SSL]	**48** [RBC,SSL]	3.8	29
Lead	8.8	11	15	1,545[c]	400[d]
Selenium	1.0	1.1	ND	10,000	5
Thallium	**2.3** [SSL]	**2.9** [SSL]	ND	140	0.7
Aluminum	13,600	15,000	17,000	2,000,000	NE
Barium	33 J	350 J	24 J	140,000	1,600
Beryllium	0.91	1.7	1.7	4,100	63
Calcium	1,050	210	2,300	NE	NE
Chromium (total)	**230** [SSL]	**280** [SSL]	**190** [SSL]	610[e]	38
Cobalt	7.6	120	9.3	120,000	NE
Copper	20	27	41	82,000	NE
Iron	76,000	75,000	58,000	610,000	NE
Magnesium	720	1,400	1,800	NE	NE
Manganese	550	3,000	520	41,000	NE
Nickel	28	55	50	41,000	130
Potassium	220	230	650	NE	NE
Sodium	1,080	ND	ND	NE	NE
Vanadium	160	160	120	14,000	6,000
Zinc	23	35	48	610,000	12,000

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for Lead for an Interim Appraoch to Assessing Risk Associated with Adult Exposures to Lead in Soil*, (EPA, 1996).

[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[e] This value is the RBC for Chromium VI.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act
SSL - Soil screening level.
66 [RBC] - Bolded, shaded value exceeds EPA Region 3 RBC.
66 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-18

Organic Subsurface Soil Analytical Results
Monitoring Well RMW1-4, Landfill Area 1, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	15 - 17 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
VOCs					
Acetone	0.010 J	ND	0.0083 J	200,000	16
Toluene	0.019	0.013	0.0089	410,000	12
BNAs	ND	ND	ND	Various	Various
Pesticides/PCBs	ND	ND	ND	Various	Various
TPH as diesel	ND	ND	ND	NE	NE
TPH as gasoline	ND	ND	ND	NE	NE
Explosives	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-19

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-1, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**70** RBC,SSL	**70** RBC,SSL	**90** RBC,SSL	**84** RBC,SSL	**54** RBC,SSL	**57** RBC,SSL	**34** RBC,SSL	3.8	29
Lead	9.1	9.2	10	9.6	11	7.9	7.8	1,545[c]	400[d]
Selenium	ND	0.71	0.79	ND	ND	ND	ND	10,000	5
Thallium	**2.2** SSL	**2.1** SSL	**2.2** SSL	**1.7** SSL	**2.0** SSL	**1.9** SSL	**1.4** SSL	140	0.7
Aluminum	20,000	22,000	28,000	22,000	19,000	16,000	12,000	2,000,000	NE
Barium	15	17	18	23	28	17	20	140,000	1,600
Beryllium	0.73	0.85	1.2	1.5	1.5	1.7	0.94	4,100	63
Calcium	760	540	660	590	530	540	380	NE	NE
Chromium total	**270 J** SSL	**250 J** SSL	**310 J** SSL	**260 J** SSL	**190 J** SSL	**200 J** SSL	**120 J** SSL	610[c]	38
Cobalt	4.4	4.4	6.2	6.4	5.5	6.4	4.2	120,000	NE
Copper	30	19	21	24	28	32	18	82,000	NE
Iron	79,000	74,000	91,000	82,000	64,000	69,000	38,000	610,000	NE
Magnesium	580	840	1,100	930	750	730	500	NE	NE
Manganese	150	130	160	140	130	130	100	41,000	NE
Nickel	26	25	35	28	23	27	18	41,000	130
Potassium	400	350	400	300	310	250	270	NE	NE
Sodium	210	250	150	ND	ND	130	ND	NE	NE
Vanadium	180	170	210	190	140	150	87	14,000	6,000
Zinc	52	38	49	42	39	46	29	610,000	12,000

Table 2-19

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-1, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.
[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for Lead for an Interim Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil*, (EPA, 1996).
[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).
[e] This value is the RBC for Chromium VI.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act
SSL - Soil screening level.
70 [RBC] - Bolded, shaded value exceeds EPA Region 3 industrial RBC.
70 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-20

Organic Subsurface Soil Analytical Results
Monitoring Well RMW2-1, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs)							EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)		
VOCs									
Toluene	0.0013 J	ND	ND	ND	ND	ND	ND	410,000	12
Carbon disulfide	ND	0.011	ND	ND	ND	ND	ND	200,000	32
BNs	ND	ND	ND	ND	ND	ND	ND	Various	Various
Pesticides/PCBs	ND	ND	ND	ND	ND	ND	ND	Various	Various
TPH as diesel	ND	ND	ND	ND	ND	ND	ND	NE	NE
TPH as gasoline	ND	ND	ND	ND	ND	ND	ND	NE	NE
Explosives	ND	ND	ND	ND	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BN - Base/neutral extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-21

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-2, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**52 (53)** RBC,SSL	**78** RBC,SSL	**46** RBC,SSL	**9.6** RBC	**4.6** RBC	**6.2** RBC	**5.0** RBC	3.8	29
Lead	11 (11)	9.6	3.0	2.2	1.9	2.2	1.9	1,545[c]	400[d]
Selenium	ND (0.82 J)	ND	1.9 J	2.9 J	1.3 J	1.8 J	1.5 J	10,000	5
Thallium	**1.8 (2.0)** SSL	**1.9** SSL	**2.2** SSL	**1.7** SSL	**2.0** SSL	**1.9** SSL	**1.4** SSL	140	0.7
Aluminum	20,000 (22,000)	17,000	9,000	4,400	2,660	2,600	2,100	2,000,000	NE
Barium	28 (37)	27	9.9	ND	ND	3.2	ND	140,000	1,600
Beryllium	0.94 (1.0)	3.1	ND	ND	ND	ND	ND	4,100	63
Calcium	3,200 (2,200)	12,000	320,000	330,000	347,000	330,000	320,000	NE	NE
Chromium total	**180 (200)** SSL	**200** SSL	**71** SSL	37	21	24	21	610[e]	38
Cobalt	8.5 (10)	17	ND	ND	ND	ND	ND	120,000	NE
Copper	25 (30)	26	6.6	3.5	ND	3.3	ND	82,000	NE
Iron	54,000 (57,000)	73,000	22,000	13,000	6,550	8,200	5,000	610,000	NE
Magnesium	630 (630)	1,700	3,600	2,200	1,690	1,500	1,400	NE	NE
Manganese	650 (1,000)	590	54	33	25	32	31	41,000	NE
Nickel	27 (25)	71	13	5.2	ND	4.2	2.7	41,000	130
Potassium	420 (530)	330	610	210	ND	170	140	NE	NE
Silver	ND (ND)	ND	ND	1.4	1.3	1.2	1.4	14,000	34
Sodium	200 (180)	140	ND	ND	ND	ND	ND	NE	NE
Vanadium	120 (130)	160	47	32	13	19	13	14,000	6,000
Zinc	42 (47)	42	32	14	8.2	7.6	5.6	610,000	12,000
Mercury	0.093 (0.094)	ND	0.041	ND	ND	ND	ND	610[f]	2

Table 2-21

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-2, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.
[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for lead for an Interim Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil*, (EPA, 1996).
[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).
[e] This value is the RBC for Chromium VI.
[f] This value is the RBC for mercuric oxide.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Conservation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act.
SSL - Soil screening level.
52 [RBC] - Bolded, shaded value exceeds EPA Region 3 RBC.
52 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-22

Organic Subsurface Soil Analytical Results
Monitoring Well RMW2-2, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs)							EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)		
VOCs	ND (ND)	ND	ND	ND	ND	ND	ND	Various	Various
BNAs	ND (ND)	ND	ND	ND	ND	ND	ND	Various	Various
Pesticides/PCBs	ND (ND)	ND	ND	ND	ND	ND	ND	Various	Various
TPH as diesel	ND (ND)	ND	ND	ND	ND	ND	ND	NE	NE
TPH as gasoline	ND (ND)	ND	ND	ND	ND	ND	ND	NE	NE
Explosives	ND (ND)	ND	ND	ND	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
ND (ND) - Sample result (duplicate sample result).
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-23

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-3, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**79** RBC,SSL	**77** RBC,SSL	**35** RBC,SSL	**45** RBC,SSL	**49** RBC,SSL		**51** RBC,SSL	3.8	29
Lead	14	12	7.8	7.5	8.6	11	13	1,545[c]	400[d]
Thallium	**2.5** SSL	**2.1** SSL	**1.8** SSL	**1.6** SSL	**2.0** SSL	**2.2** SSL	**2.0** SSL	140	0.7
Aluminum	30,000	25,000	12,100	13,000	16,000	18,000	23,000	2,000,000	NE
Barium	27	17	14	28	27	39	31	140,000	1,600
Beryllium	1.6	1.6	1.1	0.99	0.83	0.86	0.84	4,100	63
Calcium	820	650	290	330	380	470	520	NE	NE
Chromium total	**290 J** SSL	**260 J** SSL	**190 J** SSL	**160 J** SSL	**160 J** SSL	**170 J** SSL	**170 J** SSL	610[e]	38
Cobalt	9.9	10	6.6	9.5	12	12	13	120,000	NE
Copper	23	25	23	20	25	33	36	82,000	NE
Iron	ND	ND	51,300	54,000	55,000	62,000	59,300	610,000	NE
Magnesium	1,000	1,100	540	640	690	760	790	NE	NE
Manganese	250	180	170	300	810	1,700	1,500	41,000	NE
Nickel	38	37	18	20	24	27	27	41,000	130
Potassium	540	380	220	230	280	300	420	NE	NE
Vanadium	180	180	120	120	120	140	140	14,000	6,000
Zinc	50	48	34	39	45	52	60	610,000	12,000

Table 2-23

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-3, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

[a] Risk-based concentration from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.
[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for Lead for an Interim Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil*, (EPA, 1996).
[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).
[e] This value is the RBC for Chromium VI.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act.
SSL - Soil screening level.
79 [RBC] - Bolded, shaded value exceeds EPA Region 3 industrial RBC.
79 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-24

Organic Subsurface Soil Analytical Results
Monitoring Well RMW2-3, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs)							EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	19 - 21 (mg/kg)	24 - 26 (mg/kg)	29 - 31 (mg/kg)	34 - 36 (mg/kg)		
VOCs	ND	ND	ND	ND	ND	ND	ND	Various	Various
BNAs	ND	ND	ND	ND	ND	ND	ND	Various	Various
Pesticides/PCBs	ND	ND	ND	ND	ND	ND	ND	Various	Various
TPH as diesel	ND	ND	ND	ND	ND	ND	ND	NE	Various
TPH as gasoline	ND	ND	ND	ND	ND	ND	ND	NE	NE
Explosives	ND	ND	ND	ND	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.

Table 2-25

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-4, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**89 (88)** [RBC,SSL]	3.8	29
Lead	10 (15)	1,545[c]	400[d]
Selenium	2.3 (ND)	10,000	5
Thallium	**2.7 (3.2)** [SSL]	140	0.7
Aluminum	12,000 (33,000)	2,000,000	NE
Barium	33 (49)	140,000	1,600
Beryllium	2.6 (1.9)	4,100	63
Calcium	2,400 (1,400)	NE	NE
Chromium total	**280 (280)** [SSL]	610[e]	38
Cobalt	13 (9.5)	120,000	NE
Copper	21 (21)	82,000	NE
Iron	100,000 (100,000)	610,000	NE
Magnesium	2,500 (1,300)	NE	NE
Manganese	100 (150)	41,000	NE
Nickel	54 (45)	41,000	130
Potassium	430 (580)	NE	NE
Sodium	ND (210)	NE	NE
Vanadium	180 (180)	14,000	6,000
Zinc	46 (41)	610,000	12,000
Mercury	ND (0.049)	610[f]	2

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for Lead for an Interim Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil* (EPA, 1996).

[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[e] This value is the RBC for Chromium VI.

[f] This value is the RBC for mercuric oxide.

bgs - Below ground surface.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
SSL - Soil screening level.
89 (88) - Sample result (duplicate sample result).
89 [RBC] - Bolded, shaded value exceeds EPA Region 3 residential RBC.
89 [SSL] - Bolded, shaded value exceeds EPA generic SSL.

Table 2-26

Organic Subsurface Soil Analytical Results
Monitoring Well RMW2-4, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
VOCs			
Acetone	0.015 (ND)	200,000	16
Toluene	0.0054 J (0.0060 J)	410,000	12
BNAs	ND (ND)	Various	Various
Pesticides/PCBs	ND (ND)	Various	Various
TPH as diesel	ND (ND)	NE	NE
TPH as gasoline	ND (ND)	NE	NE
Explosives	ND (ND)	Various	Various

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.
VOC - Volatile organic compound.
0.015 (ND) - Sample result (duplicate sample result).

Table 2-27

Inorganic Subsurface Soil Analytical Results
Monitoring Well RMW2-5, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs) 4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)	EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
Arsenic	**41** RBC,SSL	**40** RBC,SSL	**73** RBC,SSL	3.8	29
Lead	7.3	6.9	11	1,545[c]	400[d]
Aluminum	11,000	10,000	18,000	2,000,000	NE
Barium	12	7.6	50	140,000	1,600
Beryllium	ND	0.64	2.3	4,100	63
Cadmium	2.3	3.6	6.2	2,000[e]	8
Calcium	450	460	18,000	NE	NE
Chromium total	**160** SSL	**200** SSL	**280** SSL	610[f]	38
Cobalt	3.8	4.0	19	120,000	NE
Copper	14	16	20	82,000	NE
Iron	44,000	48,000	55,000	610,000	NE
Magnesium	340	440	3,900	NE	NE
Manganese	100	140	990	41,000	NE
Nickel	16	19	53	41,000	130
Potassium	230	120	630	NE	NE
Vanadium	100	120	140	14,000	6,000
Zinc	21	22	44	610,000	12,000

[a] Risk-based concentrations from EPA Region 3 Table, April 12, 1999.

[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

[c] Adult industrial lead screening level based on *Recommendations of the Technical Review Workshop for Lead for an Interim Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil* (EPA, 1996).

[d] A screening level of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (EPA, 1994).

[e] This value is the RBC for food.

[f] This value is the RBC for Chromium VI.

bgs - Below ground surface.
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act.
EPA - U.S. Environmental Protection Agency.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
RBC - Risk-based concentration.
RCRA - Resource Conservation and Recovery Act.
SSL - Soil screening level.
41 RBC - Bolded, shaded value exceeds EPA Region 3 RBC.
41 SSL - Bolded, shaded value exceeds EPA generic SSL.

Table 2-28

Organic Subsurface Soil Analytical Results
Monitoring Well RMW2-5, Landfill Area 2, June 1997
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Parameter	Sample Depth Interval (feet bgs)			EPA Region 3 Industrial RBCs[a] (mg/kg)	EPA Generic SSLs[b] (mg/kg)
	4 - 6 (mg/kg)	9 - 11 (mg/kg)	14 - 16 (mg/kg)		
VOCs					
Acetone	ND	ND	0.0068 J	200,000	16[a]
BNAs	ND	ND	ND	Various	Various
Pesticides/PCBs	ND	ND	ND	Various	Various
TPH as diesel	ND	ND	ND	NE	NE
TPH as gasoline	ND	ND	ND	NE	NE
Explosives	ND	ND	ND	Various	Various

[a] Risk-based concentrations from EPA Region III Table, April 12, 1999.
[b] Generic SSLs (July 1996) for the migration to groundwater pathway developed using a default dilution-attenuation factor of 20.

bgs - Below ground surface.
BNA - Base neutral/acid extractable organic compound.
EPA - U.S. Environmental Protection Agency.
J - Estimated concentration.
mg/kg - Milligrams per kilogram.
ND - Not detected.
NE - Not established.
PCB - Polychlorinated biphenyl.
RBC - Risk-based concentration.
SSL - Soil screening level.
TPH - Total petroleum hydrocarbon.

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
Landfill Area 1					
Groundwater Samples - Round 1					
RMW1-1	RAFB-RMW1-1-GW-AA3001-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-2	RAFB-RMW1-2-GW-AA3002-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-3	RAFB-RMW1-3-GW-AA3003-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-4	RAFB-RMW1-4-GW-AA3004-REG			RAFB-RMW1-4-GW-AA3004MS-MS RAFB-RMW1-4-GW-AA3004MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
Groundwater Samples - Round 2					
RMW1-1	RAFB-RMW1-1-GW-AA3005-REG		RAFB-RMW1-1-GW-AA3006-FD RAFB-RMW1-1-GW-AA3007-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-2	RAFB-RMW1-2-GW-AA3008-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-3	RAFB-RMW1-3-GW-AA3009-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW1-4	RAFB-RMW1-4-GW-AA30010-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
Soil Boring - Surface and Subsurface Soils					
LF1SB01	RAFB-LF1SB01-SS-AA0001-REG	0-1	RAFB-LF1SB01-SS-AA0002-FD RAFB-LF1SB01-SS-AA0003-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB01-DS-AA0004-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF1SB01-DS-AA0005-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB02	RAFB-LF1SB02-SS-AA0006-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB02-DS-AA0007-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF1SB02-DS-AA0008-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB03	RAFB-LF1SB03-SS-AA0009-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB03-DS-AA0010-REG	TBD	RAFB-LF1SB03-DS-AA0011-FD RAFB-LF1SB03-DS-AA0012-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB03-DS-AA0013-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
LF1SB04	RAFB-LF1SB04-SS-AA0014-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB04-DS-AA0015-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF1SB04-DS-AA0016-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB05	RAFB-LF1SB05-SS-AA0017-REG	0-1		RAFB-LF1SB05-SS-AA0017MS-MS RAFB-LF1SB05-SS-AA0017MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB05-DS-AA0018-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF1SB05-DS-AA0019-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB06	RAFB-LF1SB06-SS-AA0020-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB06-DS-AA0021-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB06-DS-AA0022-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB07	RAFB-LF1SB07-SS-AA0023-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB07-DS-AA0024-REG	TBD	RAFB-LF1SB07-DS-AA0025-FD RAFB-LF1SB07-DS-AA0026-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB07-DS-AA0027-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB08	RAFB-LF1SB08-SS-AA0028-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB08-DS-AA0029-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF1SB08-DS-AA0030-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB09	RAFB-LF1SB09-SS-AA0031-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB09-DS-AA0032-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB010	RAFB-LF1SB010-SS-AA0034-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB010-DS-AA0035-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
LF1SB011	RAFB-LF1SB011-SS-AA0037-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB011-DS-AA0038-REG	TBD	RAFB-LF1SB11-DS-AA0039-FD RAFB-LF1SB11-DS-AA0040-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB012	RAFB-LF1SB012-SS-AA0042-REG	0-1		RAFB-LF1SB012-SS-AA0042MS-MS RAFB-LF1SB012-SS-AA0042MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB012-DS-AA0043-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB013	RAFB-LF1SB013-SS-AA0045-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB013-DS-AA0046-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB014	RAFB-LF1SB014-SS-AA0048-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB014-DS-AA0049-REG	TBD	RAFB-LF1SB02-DS-AA0050-FD RAFB-LF1SB02-DS-AA0051-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB015	RAFB-LF1SB015-SS-AA0053-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB015-DS-AA0054-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB016	RAFB-LF1SB016-SS-AA0056-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB016-DS-AA0057-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB017	RAFB-LF1SB017-SS-AA0059-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB017-DS-AA0060-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB018	RAFB-LF1SB018-SS-AA0062-REG	0-1	RAFB-LF1SB018-SS-AA0063-FD RAFB-LF1SB018-SS-AA0064-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF1SB018-DS-AA0065-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB019	RAFB-LF1SB019-SS-AA0067-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB019-DS-AA0068-REG	TBD		RAFB-LF1SB019-DS-AA0068MS-MS RAFB-LF1SB019-DS-AA0068MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SB020	RAFB-LF1SB020-SS-AA0070-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SB020-DS-AA0071-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
Surface Water/Sediment Samples					
LF1SWSD01	RAFB-LF1SWSD01-SD-AA1000-REG	0-1		RAFB-LF1SWSD01-SD-AA1000MS-MS RAFB-LF1SWSD01-SD-AA1000MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SWSD01-SW-AA2000-REG	0-1		RAFB-LF1SWSD01-SW-AA2000MS-MS RAFB-LF1SWSD01-SW-AA2000MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SWSD02	RAFB-LF1SWSD02-SD-AA1001-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SWSD02-SW-AA2001-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SWSD03	RAFB-LF1SWSD03-SD-AA1002-REG	0-1	RAFB-LF1SWSD03-SD-AA1003-FD RAFB-LF1SWSD03-SD-AA1004-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SWSD03-SW-AA2002-REG	0-1	RAFB-LF1SWSD03-SW-AA2003-FD RAFB-LF1SWSD03-SW-AA2004-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF1SWSD04	RAFB-LF1SWSD04-SD-AA1005-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF1SWSD03-SW-AA2005-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
Landfill Area 2					
Groundwater Samples - Round 1					
RMW2-1	RAFB-RMW2-1-GW-AB3001-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-2	RAFB-RMW2-2-GW-AB3002-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-3	RAFB-RMW2-3-GW-AB3003-REG		RAFB-RMW2-3-GW-AB3004-FD RAFB-RMW2-3-GW-AB3005-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-4	RAFB-RMW2-4-GW-AB3006-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-5	RAFB-RMW2-5-GW-AB3007-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
Groundwater Samples - Round 2					
RMW2-1	RAFB-RMW2-1-GW-AB3008-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-2	RAFB-RMW2-2-GW-AB3009-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-3	RAFB-RMW2-3-GW-AB3010-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-4	RAFB-RMW2-4-GW-AB3011-REG			RAFB-RMW2-4-GW-AB3011MS-MS RAFB-RMW2-4-GW-AB3011MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity
RMW2-5	RAFB-RMW2-5-GW-AB3012-REG				VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals (total and dissolved), pesticides, PCBs, Anions, TDS, TSS, alkalinity

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
Soil Boring - Surface and Subsurface Soils					
LF2SB01	RAFB-LF2SB01-SS-AB0001-REG	0-2	RAFB-LF2SB01-SS-AB0002-FD RAFB-LF2SB01-SS-AB0003-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB01-DS-AB0004-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF2SB01-DS-AB0005-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB02	RAFB-LF2SB02-SS-AB0006-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB02-DS-AB0007-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB02-DS-AB0008-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB03	RAFB-LF2SB03-SS-AB0009-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB03-DS-AB0010-REG	TBD	RAFB-LF2SB03-DS-AB0011-FD RAFB-LF2SB03-DS-AB0012-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF2SB03-DS-AB0013-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB04	RAFB-LF2SB04-SS-AB0014-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB04-DS-AB0015-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB04-DS-AB0016-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB05	RAFB-LF2SB05-SS-AB0017-REG	0-2		RAFB-LF2SB05-SS-AB0017MS-MS RAFB-LF2SB05-SS-AB0017MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB05-DS-AB0018-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF2SB05-DS-AB0019-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB06	RAFB-LF2SB06-SS-AB0020-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB06-DS-AB0021-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB06-DS-AB0022-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
LF2SB07	RAFB-LF2SB07-SS-AB0023-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB07-DS-AB0024-REG	TBD	RAFB-LF2SB07-DS-AB0025-FD RAFB-LF2SB07-DS-AB0026-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB07-DS-AB0027-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB08	RAFB-LF2SB08-SS-AB0028-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB08-DS-AB0029-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF2SB08-DS-AB0030-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB09	RAFB-LF2SB09-SS-AB0031-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB09-DS-AB0032-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB09-DS-AB0033-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB010	RAFB-LF2SB010-SS-AB0034-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB010-DS-AB0035-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB010-DS-AB0036-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB011	RAFB-LF2SB011-SS-AB0037-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB011-DS-AB0038-REG	TBD	RAFB-LF2SB11-DS-AB0039-FD RAFB-LF2SB11-DS-AB0040-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, geotechnical
	RAFB-LF2SB011-DS-AB0041-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB012	RAFB-LF2SB012-SS-AB0042-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB012-DS-AB0043-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB012-DS-AB0044-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB013	RAFB-LF2SB013-SS-AB0045-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB013-DS-AB0046-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
LF2SB014	RAFB-LF2SB014-SS-AB0048-REG	0-2		RAFB-LF2SB02-SS-AB0048MS-MS RAFB-LF2SB02-SS-AB0048MD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB014-DS-AB0049-REG	TBD	RAFB-LF2SB02-DS-AB0050-FD RAFB-LF2SB02-DS-AB0051-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB015	RAFB-LF2SB015-SS-AB0053-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB015-DS-AB0054-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB016	RAFB-LF2SB016-SS-AB0056-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB016-DS-AB0057-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB017	RAFB-LF2SB017-SS-AB0059-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB017-DS-AB0060-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB018	RAFB-LF2SB018-SS-AB0062-REG	0-2	RAFB-LF2SB018-SS-AB0063-FD RAFB-LF2SB018-SS-AB0064-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB018-DS-AB0065-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB019	RAFB-LF2SB019-SS-AB0067-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB019-DS-AB0068-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB020	RAFB-LF2SB020-SS-AB0070-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB020-DS-AB0071-REG	TBD		RAFB-LF2SB020-DS-AB0071-MS-MS RAFB-LF2SB020-DS-AB0071-MSD-MSD	VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB021	RAFB-LF2SB021-SS-AB0073-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB021-DS-AB0074-REG	TBD	RAFB-LF2SB021-DS-AB0075-FD RAFB-LF2SB021-DS-AB0076-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB022	RAFB-LF2SB022-SS-AB0078-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB022-DS-AB0079-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SB023	RAFB-LF2SB023-SS-AB0081-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SB023-DS-AB0082-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

Table 3-1

Landfill Area 1 and Landfill Area 2 Sampling Requirements
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Sample Location	Sample Designation [a]	Sample Depth [b]	QA/QC Sample Designation[c]		Analytical Suite[d,e,f]
			Field Duplicates Split Samples	MS/MSD	
LF2SB024	RAFB-LF2SB024-SS-AB0084-REG	0-2			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL Metals, pesticides, PCBs, TOC, grain size
	RAFB-LF2SB024-DS-AB0085-REG	TBD			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
Surface Water/Sediment Samples					
LF2SWSD01	RAFB-LF2SWSD01-SD-AB1000-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SWSD01-SW-AB2000-REG	0-1			VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
LF2SWSD02	RAFB-LF2SWSD02-SD-AB1001-REG	0-1	RAFB-LF2SWSD02-SD-AB1002-FD RAFB-LF2SWSD02-SD-AB1003-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs
	RAFB-LF2SWSD02-SW-AB2001-REG	0-1	RAFB-LF2SWSD02-SW-AB2002-FD RAFB-LF2SWSD02-SW-AB2003-SPLT		VOCs, SVOCs, TPH-DRO, TPH-GRO, TAL metals, pesticides, PCBs

[a] The sample designation is composed of five segments: (1) the facility name (RAFB); (2) the site designation (RMW); (3) sample location ID (AA3001); (4) sample type (GW); and (5) sample purpose (REG). Please refer to Chapter 6.0 of the SAP for more detail about sample naming.

[b] TBD - to be determined. Depths of these samples will be determined based on screening information and depth to bedrock.

[c] QA Split samples are planned but will only be collected at the direction of the USACE.

[d] Additionally, three subsurface soil samples from within Landfill Area 1 and up to five subsurface soil samples from within Landfill Area 2 will be analyzed for the presence of explosives and propellants, including perchlorate.These same samples may also be analyzed for dioxin and furans if there is evidence of burned materials.

[e] Additionally, ten surface soil locations will be analyzed for TOC and grain size and 5 subsurface soil samples will be analyzed for the following geotechnical parameters - Bulk soil density, total soil porosity, air-filled porosity, water-filled porosity, particle density and fractional organic carbon, at each landfill.

[f] Anions include: chloride, sulfate, nitrate, phosphate, and fluoride.

MS - Matrix spike.
MSD - Matrix spike duplicate.
PCB - Polychlorinated biphenyl.
QA - Quality assurance.
QC - Quality control.
SVOC - Semivolatile organic compound.
TDS - Total dissolved solids
TPM - Total petroleum hydrocarbon.
TSS - Total suspended solids
VOC - Volatile organic compound.

Table 3-2

Sampling and Analytical Requirements for Landfill Area 1 and Landfill Area 2 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Matrix	Parameter	Analytical Method	Total No. of Samples [a]	QC Samples [a]					QA Samples [a]			Sample Container	Preservation Requirements	Holding Time	Approx. Total No. of Containers
				No. of Dups	No. of Sample Rinsates	No. of Trip Blanks	No. of MS/MSD Pairs	Total No. of Samples	No. of Splits	No. of Trip Blanks	Total No. of QA Samples				
Landfill Area 1															
Groundwater	VOCs	8260B	8	1	0	2	1	12	1	0	1	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	39
	SVOCs	8270C	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	22
	TAL Metals	6010B/7000	8	1	0	0	1	10	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	11
	TAL Metals (fil)	6010B/7000	8	1	0	0	1	10	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	11
	TPH-DRO	8015M	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	14 days	11
	TPH - GRO	8015M	8	1	0	0	1	10	1	0	1	(3) 40 mL VOA vial	Cool	14 days	11
	PCBs	8082	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	11
	Pesticides	8081	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	11
	Anions	EPA 300	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	various	11
	Alkalinity	EPA 310.1	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	14 days	11
	TDS	EPA 160.1	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	7 days	11
	TSS	EPA 160.2	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	7 days	11
Soil Borings	VOCs	8260B	48	6	0	0	3	57	3	0	3	4 oz glass	Cool	14 days	60
(Surface &	SVOCs	8270C	48	6	0	0	3	57	3	0	3	4 oz glass	Cool	7 days ext/40 days analysis	60
Deep Soils)	Pesticides	8081	48	6	0	0	3	54	3	0	3	4 oz glass	Cool	7 days ext/40 days analysis	57
	PCBs	8082	48	6	0	0	3	54	3	0	3	4 oz glass	Cool	7 days ext/40 days analysis	57
	TPH-DRO	8015M	48	6	0	0	3	57	3	0	3	4 oz glass	Cool	14 days	60
	TPH - GRO	8015M	48	6	0	0	3	57	3	0	3	4 oz glass	Cool	14 days	60
	TAL Metals	6010B/7000	48	6	0	0	3	57	3	0	3	4 oz glass	Cool	6 months	60
	Explosives	8330	3	0	0	0	0	3	0	0	0	4 oz glass	Cool	7 days ext/40 days analysis	3
	Propellants, Perchlorate	6850	3	0	0	0	0	3	0	0	0	4 oz glass	Cool	7 days ext/40 days analysis	3
	Dioxin/Furan [b]	8290	3	0	0	0	0	3	0	0	0	4 oz glass	Cool	7 days ext/40 days analysis	3
	TOC	9060	10	0	0	0	0	10	0	0	0	4 oz glass	Cool	14 days	10
	Grain Size	ASTMD422	10	0	0	0	0	10	0	0	0	8 oz glass	Cool	ASAP	10
	Geotechnical [c]	various	5	0	0	0	0	5	0	0	0	TBD	Cool	ASAP	5
Surface Water	VOCs	8260B	4	0	0	1	1	6	0	0	0	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	18
	SVOCs	8270C	4	1	0	0	1	6	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	14
	Pesticides	8081	4	1	0	0	1	6	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	14
	PCBs	8082	4	1	0	0	1	6	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	14
	TPH-DRO	8015M	4	1	0	0	1	6	1	0	1	(2) 1L amber glass	Cool	14 days	14
	TPH - GRO	8015M	4	1	0	0	1	6	1	0	1	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	21
	TAL Metals	6010B/7000	4	1	0	0	1	6	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	7

Table 3-2

Sampling and Analytical Requirements for Landfill Area 1 and Landfill Area 2 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Matrix	Parameter	Analytical Method	Total No. of Samples [a]	QC Samples [a]					QA Samples [a]			Sample Container	Preservation Requirements	Holding Time	Approx. Total No. of Containers
				No. of Dups	No. of Sample Rinsates	No. of Trip Blanks	No. of MS/MSD Pairs	Total No. of Samples	No. of Splits	No. of Trip Blanks	Total No. of QA Samples				
Sediment	VOCs	8260B	4	1	0	0	1	6	1	0	1	4 oz glass	Cool	14 days	7
	SVOCs	8270C	4	1	0	0	1	6	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	7
	Pesticides	8081	4	1	0	0	1	5	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	6
	PCBs	8082	4	1	0	0	1	5	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	6
	TPH-DRO	8015M	4	1	0	0	1	6	1	0	1	4 oz glass	Cool	14 days	7
	TPH - GRO	8015M	4	1	0	0	1	6	1	0	1	4 oz glass	Cool	14 days	7
	TAL Metals	6010B/7000	4	1	0	0	1	6	1	0	1	4 oz glass	Cool	6 months	7
Landfill Area 2															
Groundwater	VOCs	8260B	10	1	0	2	1	14	1	0	1	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	45
	SVOCs	8270C	10	1	0	0	1	12	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	26
	TAL Metals	6010B/7000	10	1	0	0	1	12	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	13
	TAL Metals (fil)	6010B/7000	10	1	0	0	1	12	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	13
	TPH-DRO	8015M	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	14 days	11
	TPH - GRO	8015M	8	1	0	0	1	10	1	0	1	(3) 40 mL VOA vial	Cool	14 days	11
	PCBs	8082	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	11
	Pesticides	8081	8	1	0	0	1	10	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	11
	Anions	EPA 300	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	various	11
	Alkalinity	EPA 310.1	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	14 days	11
	TDS	EPA 160.1	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	7 days	11
	TSS	EPA 160.2	8	1	0	0	1	10	1	0	1	1 L HDPE	Cool	7 days	11
Soil Borings	VOCs	8260B	60	7	0	0	3	70	7	0	7	4 oz glass	Cool	14 days	77
(Surface &	SVOCs	8270C	60	7	0	0	3	70	7	0	7	4 oz glass	Cool	7 days ext/40 days analysis	77
Deep Soils)	Pesticides	8081	60	7	0	0	3	67	7	0	7	4 oz glass	Cool	7 days ext/40 days analysis	74
	PCBs	8082	60	7	0	0	3	67	7	0	7	4 oz glass	Cool	7 days ext/40 days analysis	74
	TPH-DRO	8015M	60	7	0	0	3	70	7	0	7	4 oz glass	Cool	14 days	77

Table 3-2

Sampling and Analytical Requirements for Landfill Area 1 and Landfill Area 2 Former Ramey Air Force Base, Aguadilla, Puerto Rico

Matrix	Parameter	Analytical Method	Total No. of Samples [a]	QC Samples [a]					QA Samples [a]			Sample Container	Preservation Requirements	Holding Time	Approx. Total No. of Containers
				No. of Dups	No. of Sample Rinsates	No. of Trip Blanks	No. of MS/MSD Pairs	Total No. of Samples	No. of Splits	No. of Trip Blanks	Total No. of QA Samples				
	TPH - GRO	8015M	60	7	0	0	3	70	7	0	7	4 oz glass	Cool	14 days	77
	TAL Metals	6010B/7000	60	7	0	0	3	70	7	0	7	4 oz glass	Cool	6 months	77
	Explosives	8330	5	0	0	0	0	5	0	0	0	4 oz glass	Cool	7 days ext/40 days analysis	5
	Propellants, Perchlorate	6850	5	0	0	0	0	5	0	0	0	4 oz glass	Cool	7 days ext/40 days analysis	5
	Dioxin/Furan [b]	8290	5	0	0	0	0	5	0	0	0	4 oz glass	Cool	days analysis	5
	TOC	9060	10	0	0	0	0	10	0	0	0	4 oz glass	Cool	14 days	10
	Grain Size	ASTMD422	10	0	0	0	0	10	0	0	0	8 oz glass	Cool	ASAP	10
	Geotechnical [c]	various	5	0	0	0	0	5	0	0	0	TBD	Cool	ASAP	5
Surface Water	VOCs	8260B	2	1	0	1	1	5	1	0	1	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	18
	SVOCs	8270C	2	1	0	0	1	4	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	10
	Pesticides	8081	2	1	0	0	1	4	1	0	1	(2) 1L amber glass	Cool	7 days ext/40 days analysis	10
	PCBs	8082	2	1	0	0	1	4	1	0	1	(2) 1L amber glass	Cool	days analysis	10
	TPH-DRO	8015M	2	1	0	0	1	4	1	0	1	(2) 1L amber glass	Cool	14 days	10
	TPH - GRO	8015M	2	1	0	0	1	4	1	0	1	(3) 40 mL VOA vial	Cool, HCL pH<2	14 days	15
	TAL Metals	6010B/7000	2	1	0	0	1	4	1	0	1	(1) 1L Poly	Cool, HNO_3 to pH <2	6 months	5
Sediment	VOCs	8260B	2	1	0	0	1	4	1	0	1	4 oz glass	Cool	14 days	5
	SVOCs	8270C	2	1	0	0	1	4	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	5
	Pesticides	8081	2	1	0	0	1	3	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	4
	PCBs	8082	2	1	0	0	1	3	1	0	1	4 oz glass	Cool	7 days ext/40 days analysis	4
	TPH-DRO	8015M	2	1	0	0	1	4	1	0	1	4 oz glass	Cool	14 days	5
	TPH - GRO	8015M	2	1	0	0	1	4	1	0	1	4 oz glass	Cool	14 days	5
	TAL Metals	6010B/7000	2	1	0	0	1	4	1	0	1	4 oz glass	Cool	6 months	5

Note: Number of trip blanks is estimated. One trip blank will be included in each cooler shipment containing aqueous VOC samples and equipment rinsate samples

[a] All quantities are estimated and may change due to field conditions.
[b] Dioxin/Furans will only be analyzed if burned materials are encountered.
[c] Geotechnical - Bulk soil density, total soil porosity, air-filled porosity, water-filled porosity, particle density and fractional organic carbon

PCB - Polychlorinated biphenyl.
QA - Quality assurance.
QC - Quality control.
SVOC - Semivolatile organic compound.
TAL - Target analyte list.
VOC - Volatile organic compound.
DRO - Diesel range organics.
GRO - Gasoline range organics.

Table 4-1

Human Receptors for the Landfills
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Source Medium	Model	Exposure Medium	Exposure Pathway
LANDFILL 1			
Off-Site Consumer of Animal Agriculture Products			
Soil	Soil-to-beef bioaccumulation	Beef	Ingestion of "homegrown" beef
	Soil-to-milk bioaccumulation	Milk	Ingestion of "homegrown" milk
Youthful Trespasser/Young Child Recreational Receptor[a]			
Soil	None	Soil	Incidental ingestion
			Dermal contact
	Airborne dust from wind erosion of soil	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation
Off-Site Resident			
Groundwater	None	Tap water	Ingestion
			Dermal contact
	Tap water-to-air volatilization	Shower room air	Inhalation
LANDFILL 2			
Farm Worker			
Soil	None	Soil	Incidental ingestion
			Dermal contact
	Activity-driven dust-loading factor	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation
	Soil-to-beef bioaccumulation	Beef	Ingestion of "homegrown" beef
	Soil-to-milk bioaccumulation	Milk	Ingestion of "homegrown" milk
	Soil-to-plant bioaccumulation	Fruits and vegetables	Ingestion of "homegrown" fruits and vegetables
Youthful Trespasser/Young Child Recreational Receptor[a]			
Soil	None	Soil	Incidental ingestion
			Dermal contact
	Airborne dust from wind erosion of soil	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation
Groundskeeper			
Soil	None	Soil	Incidental ingestion
			Dermal contact
	Airborne dust from wind erosion of soil	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation
Groundwater	None	Tap water	Ingestion
			Dermal contact
Resident			
Soil	None	Soil	Incidental ingestion
			Dermal contact

Table 4-1

Human Receptors for the Landfills
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Source Medium	Model	Exposure Medium	Exposure Pathway
	Airborne dust from wind erosion of soil	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation
	Soil-to-plant bioaccumulation	Fruits and vegetables	Ingestion of "homegrown" fruits & vegetables
Resident (continued)			
Groundwater	None	Tap water	Ingestion
			Dermal contact
	Tap water-to-air volatilization	Shower room air	Inhalation
Construction Worker			
Soil	None	Soil	Incidental ingestion
			Dermal contact
	Construction-driven dust-loading factor	Air	Inhalation
	Soil-to-air volatilization	Air	Inhalation

[a] Both the young child recreational receptor and the youthful trespasser will be evaluated. The exposure pathways for these two receptors are identical.

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a]
Landfill Sites
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Ingestion of Homegrown Beef							
Beef ingestion rate (IR_b), g/day	Adult: 150 Child: 60	NA	NA	Adult: 150 Child: 60	NA	NA	NA
Fraction of beef homegrown (FI_b), unitless	1	NA	NA	1	NA	NA	NA
Exposure frequency (EF), days/year	350	NA	NA	350	NA	NA	NA
Exposure duration (ED), years	Adult: 24 Child: 6	NA	NA	Adult: 24 Child: 6	NA	NA	NA
Body weight (BW), kg	Adult: 70 Child: 15	NA	NA	Adult: 70 Child: 15	NA	NA	NA
Averaging time, noncancer (AT), days[b]	Child: 2190	NA	NA	Adult: 8760 Child: 2190	NA	NA	NA
Averaging time, cancer (AT), days[c]	25550	NA	NA	25550	NA	NA	NA
Ingestion of Homegrown Milk							
Milk ingestion rate (IR_m), g/day	Adult: 366 Child: 662	NA	NA	Adult: 366 Child: 662	NA	NA	NA
Fraction of milk homegrown (FI_b), unitless	1	NA	NA	1	NA	NA	NA
Exposure frequency (EF), days/year	350	NA	NA	350	NA	NA	NA
Exposure duration (ED), years	Adult: 24 Child: 6	NA	NA	Adult: 24 Child: 6	NA	NA	NA

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a]
Landfill Sites
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Body weight (BW), kg	Adult: 70 Child: 15	NA	NA	Adult: 70 Child: 15	NA	NA	NA
Averaging time, noncancer (AT), days[b]	Child: 2190	NA	NA	Adult: 8760 Child: 2190	NA	NA	NA
Averaging time, cancer (AT), days[c]	25550	NA	NA	25550	NA	NA	NA
Incidental Ingestion of Soil							
Soil incidental ingestion rate (IR_s), mg/day	NA	100	200	100	100	Adult: 100 Child: 200	330
Fraction of daily soil exposure attributed to site (FL_s), unitless	NA	1	1	1	1	1	1
Exposure frequency (EF), days/year	NA	52	52	250	225	350	225
Exposure duration (ED), years	NA	10	6	30	25	Adult: 24 Child: 6	0.5
Body weight (BW), kg	NA	45	15	70	70	Adult: 70 Child: 15	70
Averaging time, noncancer (AT), days[b]	NA	3650	2190	Adult: 10,950	9,125	Child: 2190	183
Averaging time, cancer (AT), days[c]	NA	25550	25550	25550	25550	25550	25550
Inhalation of VOCs and Resuspended Dust from Soil							
Inhalation rate (IR_a), m^3/hour	NA	0.56	0.35	2.5	2.5	Adult: 0.63 Child: 0.35	2.5
Exposure time (ET_a), hours/day	NA	8	8	8	8	24	8

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a]
Landfill Sites
Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Exposure frequency (EF), days/year	NA	52	52	250	225	350	250
Exposure duration (ED), years	NA	10	6	30	25	Adult: 24 Child: 6	0.5
Body weight (BW), kg	NA	45	15	70	70	Adult: 70 Child: 15	70
Averaging time, noncancer (AT), days[b]	NA	3650	2190	Adult: 10,950	9,125	Child: 2190	183
Averaging time, cancer (AT), days[c]	NA	25550	25550	25550	25550	25550	25550
Dermal Contact with Soil							
Fraction of daily soil exposure attributed to site (FI_d), unitless	NA	0.5	0.5	1	1	1	1
Body surface area exposed to soil (SA), cm^2	NA	3900	2500	5000	5000	Adult: 5000 Child: 2500	5000
Soil-to-skin adherence factor (AF), mg/cm^2	NA	0.2	0.2	0.4	0.1	Adult: 0.07 Child: 0.2	0.3
Dermal absorption factor (ABS), unitless	NA	csv	csv	csv	csv	csv	csv
Exposure frequency (EF), days/year	NA	52	52	250	225	350	225
Exposure duration (ED), years	NA	10	6	30	25	Adult: 24 Child: 6	0.5
Body weight (BW), kg	NA	45	15	70	70	Adult: 70 Child: 15	70

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a] Landfill Sites Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Averaging time, noncancer (AT), days[b]	NA	3650	2190	Adult: 10,950	9,125	Child: 2190	183
Averaging time, cancer (AT), days[c]	NA	25550	25550	25550	25550	25550	25550
Ingestion of Homegrown Fruits and Vegetables							
Fruits ingestion rate (IR_f), g dry weight/day	NA	NA	NA	Adult: 45 Child: 20	NA	Adult:45 Child: 20	NA
Vegetables ingestion rate (IR_v), g dry weight/day	NA	NA	NA	Adult: 48 Child: 21	NA	Adult: 48 Child: 21	NA
Fraction of fruits and vegetables homegrown (FI_p), unitless	NA	NA	NA	1	NA	NA	NA
Exposure frequency (EF), days/year	NA	NA	NA	350	NA	350	NA
Exposure duration (ED), years	NA	NA	NA	Adult: 24 Child: 6	NA	Adult: 24 Child: 6	NA
Body weight (BW), kg	NA	NA	NA	Adult: 70 Child: 15	NA	Adult: 70 Child: 15	NA
Averaging time, noncancer (AT), days[b]	NA	NA	NA	Adult: 8760 Child: 2190	NA	Child: 2190	NA
Averaging time, cancer (AT), days[c]	NA	NA	NA	25550	NA	25550	NA
General Variables							
Exposure duration (ED) years	NA	NA	NA	NA	25[a]	Child: 6[b] Adult: 24[b]	NA

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a] Landfill Sites Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Body weight (BW), kilogram	NA	NA	NA	NA	70[a]	Child: 15[b] Adult: 70[a]	NA
Averaging time, noncancer (AT), days[c]	NA	NA	NA	NA	9125	Child: 2190 Adult: 8760	NA
Averaging time, cancer (AT), days[c]	NA	NA	NA	NA	25550	25550	NA
Inhalation of VOCs from Groundwater							
Exposure time (ET), hours/day	NA	NA	NA	NA	NA	Adult: 0.92[d] Child: NA	NA
Inhalation rate (IR[a]) cubic meters/hour	NA	NA	NA	NA	NA	Adult: 0.63 Child: NA	NA
Exposure frequency (EF), days/year	NA	NA	NA	NA	250[a]	350[a] Child: NA	NA
Drinking Water Ingestion of Groundwater							
Fraction exposed to contaminated medium ($F1_{gw}$), unitless	NA	NA	NA	NA	1[f]	1[f]	NA
Drinking water ingestion rate (IR_{gw}), Liters/day	NA	NA	NA	NA	2	Child: 1[b] Adult: 2[a]	NA
Exposure frequency (EF), days/year	NA	NA	NA	NA	250[a]	Adult: 350[a] Child: NA	NA
Dermal Contact with Groundwater							
Fraction exposed to contaminated medium (Fl_{gw}), unitless	NA	NA		NA	1a	1a	NA

Table 4-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors[a] Landfill Sites Former Ramey Air Force Base, Aguadilla, Puerto Rico

Pathway Variable	Off-Site Consumer of Animal Agriculture Products	Youthful Trespasser	Young Child Recreational Receptor	Farm Worker	Grounds-keeper	Resident	Construction Worker
Body surface area exposed to water (Sa_{gw}), square centimeters	NA	NA		NA	3300[a]	Child: 6600[f] Adult: 20000[f]	NA
Permeability coefficient (PC), centimeter/hour	NA	NA		NA	cvs	cvs	NA
Exposure time (ET_{gw}), hours/day	NA	NA		NA	0.5	Child: 1 Adult: 0.58	NA
Exposure frequency (EF), days/year	NA	NA		NA	250[a]	350[a]	NA

g – Gram.
kg – Kilogram.
mg/day – Milligrams per day.
m^3/hour – Cubic meters per hour.
NA - Not applicable to this receptor.
csv - Chemical-specific value.
VOC - Volatile organic compound.
[a] Please see Section 4.3.2 for justification and documentation of the exposure variable values.
[b] Product of ED x 365 days/year.
[c] Product of assumed lifetime of 70 years (U.S. Environmental Protection Agency, 1991, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final*, Office of Solid Waste and Emergency Response, Washington, DC, OSWER Directive 9285.6-03, 25 March).
[d] Refer to shower model described in Section 4.3.3.6.

FIGURES

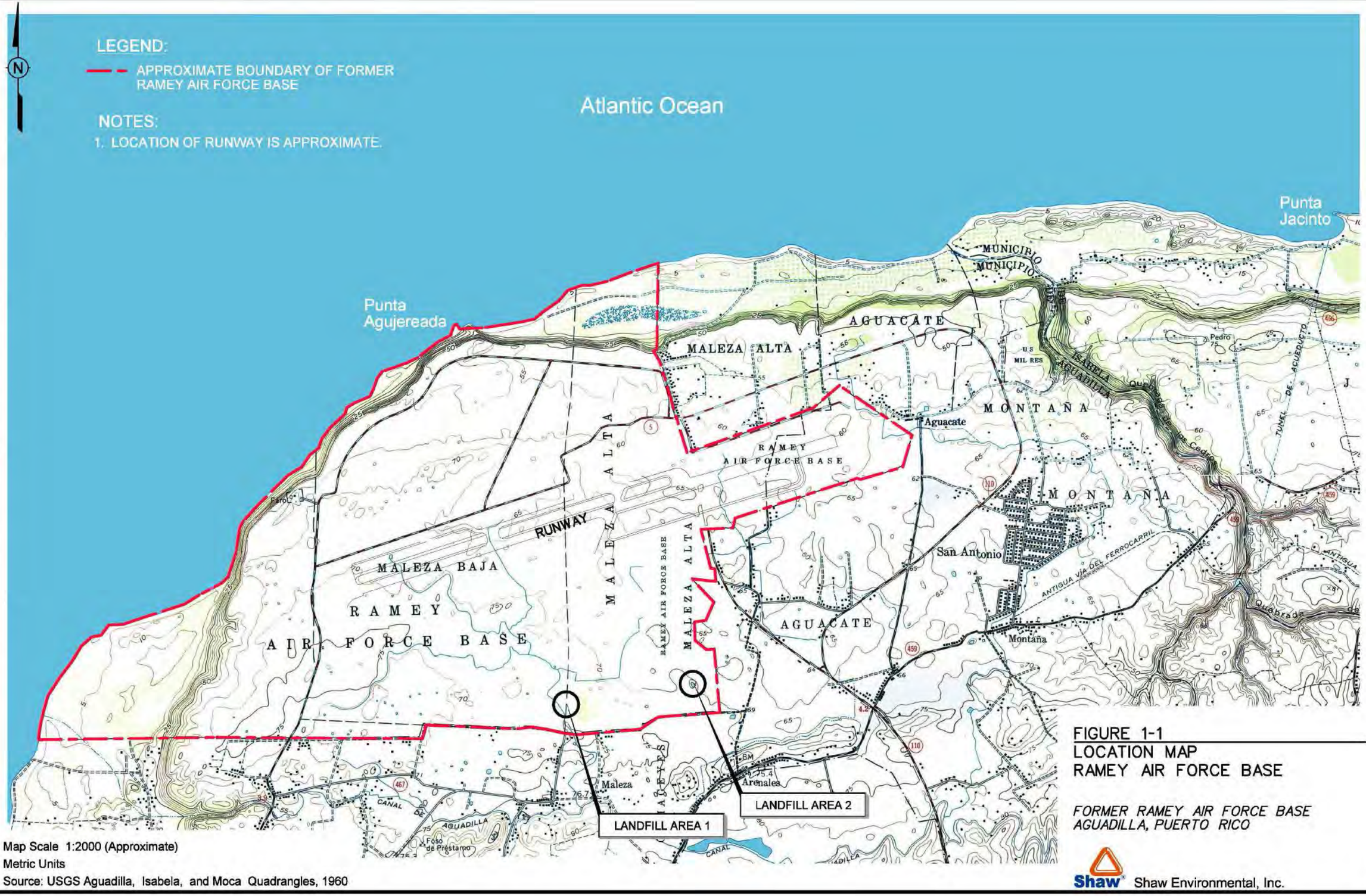

FIGURE 1-1
LOCATION MAP
RAMEY AIR FORCE BASE

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

Shaw Environmental, Inc.

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TECH. REVIEW: K. CUNNINGHAM
PROJ. MGR.: K. CUNNINGHAM
INITIATOR: B. GORISCH
CADD REVIEW: C.E. TUMLIN
STARTING DATE: 5MAY10
DRAWN BY: C.E. TUMLIN
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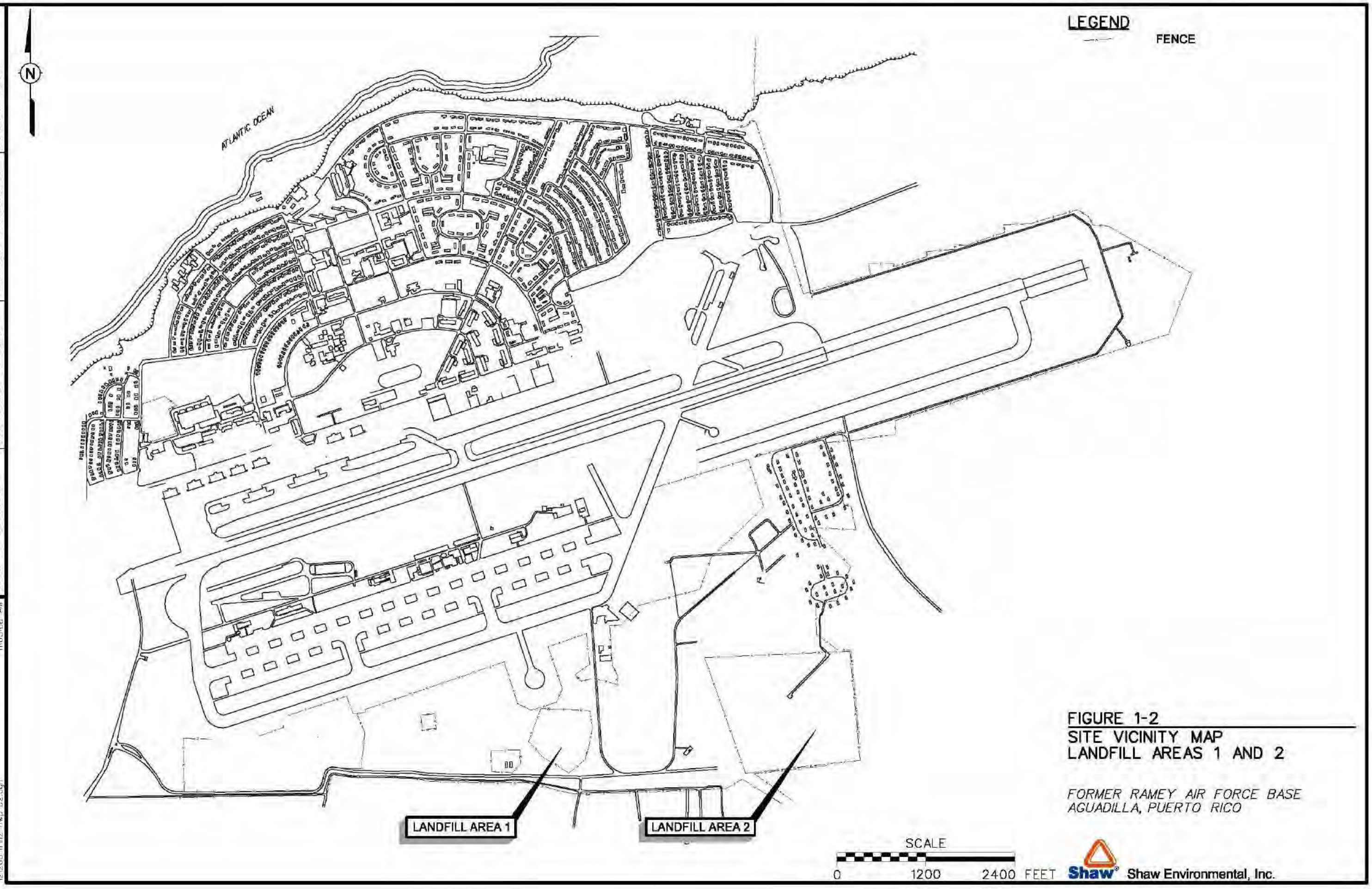

FIGURE 1-2
SITE VICINITY MAP
LANDFILL AREAS 1 AND 2

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

STARTING DATE: 5MAY10	INITIATOR: B. GORISCH	TECH. REVIEW: K.CUNNINGHAM	DWG. NO.: 121205-lfn2-rwp-02.dgn
DRAWN BY: C.E.TUMLIN	DADD REVIEW: C.E.TUMLIN	PROJ. MGR.: K. CUNNINGHAM	PROJ. NO.: 121205

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smccawley
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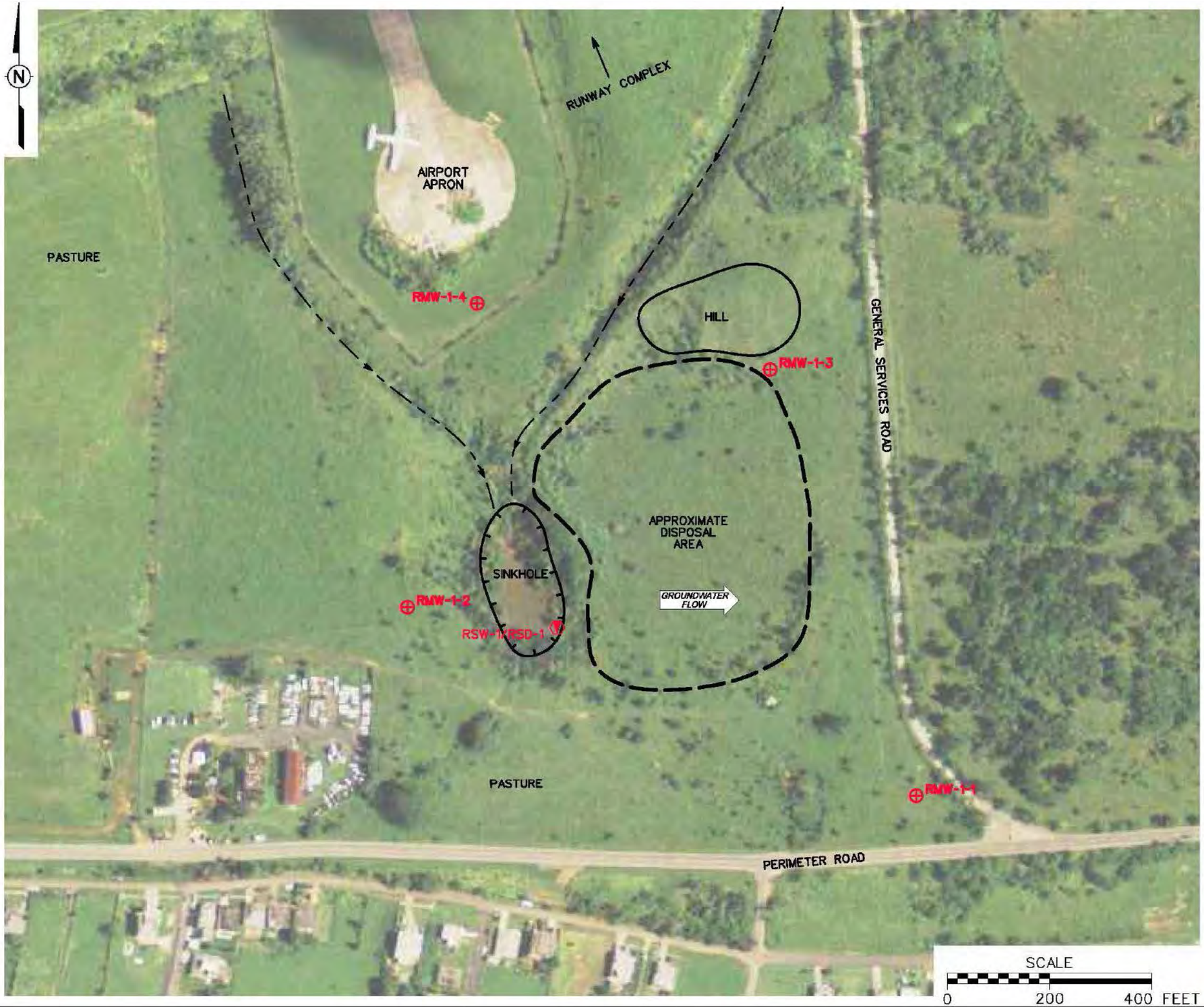

LEGEND

- APPROXIMATE DISPOSAL AREA
- DRAINAGE CHANNEL AND FLOW DIRECTION
- RMW-1-1 MONITORING WELL
- GROUNDWATER FLOW — GROUNDWATER FLOW DIRECTION
- SURFACE WATER/ SEDIMENT SAMPLE LOCATION

NOTE

1. BACKGROUND IMAGE OBTAINED FROM SEPT. 21, 2004 ORTHOPHOTO ORIGINALLY DEVELOPED BY THE USACE.

FIGURE 2-1
SITE MAP
LANDFILL AREA 1

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

Shaw® Shaw Environmental, Inc.

STARTING DATE: 27AUG07	INITIATOR: Z.PARHAM	TECH. REVIEW: K.CUNNINGHAM	DWG. NO.: 121205-lfln2-rlwp-03.dgn
DRAWN BY: C.E.TUMLIN	CADD REVIEW: C.E.TUMLIN	PROJ. MGR.: G.QUARLES	PROJ. NO.: 121205

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121205-lfln2-rlwp-03.dgn

FIGURE 2-2
1983 AERIAL PHOTOGRAPH
LANDFILL AREAS 1 AND 2

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

SCALE
0 600 1200 FEET

Shaw® Shaw Environmental, Inc.

STARTING DATE: 5MAY10	INITIATOR: K.CUNNINGHAM	TECH. REVIEW: K.CUNNINGHAM	DWG. NO.: 121205-rfrh2-rlwp-04.dgn
DRAWN BY: C.E.TUMLIN	CADD REVIEW: C.E.TUMLIN	PROJ. MGR.: K. CUNNINGHAM	PROJ. NO.: 121205

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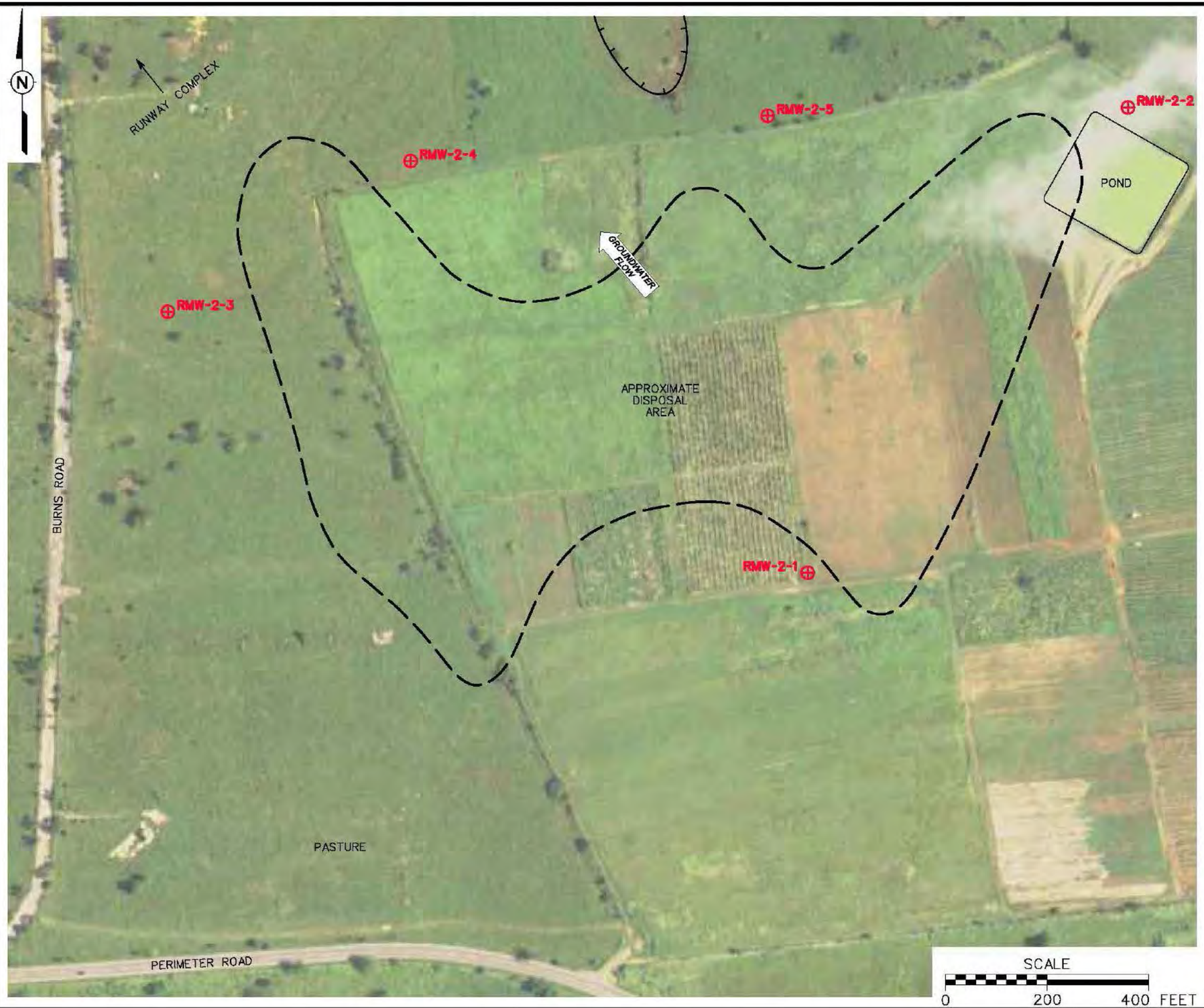

LEGEND

APPROXIMATE DISPOSAL AREA

RMW-2-1 MONITORING WELL

GROUNDWATER FLOW — GROUNDWATER FLOW DIRECTION

NOTE

1. BACKGROUND IMAGE OBTAINED FROM SEPT. 21, 2004 ORTHOPHOTO ORIGINALLY DEVELOPED BY THE USACE.

FIGURE 2-3
SITE MAP
LANDFILL AREA 2

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

Shaw® Shaw Environmental, Inc.

STARTING DATE: 29APR10	INITIATOR: E. GORISCH	TECH. REVIEW: K.CUNNINGHAM	DWG. NO.: 121205-lfln2-rlwp-05.dgn
DRAWN BY: S. MCCAWLEY	CADD REVIEW: S. MCCAWLEY	PROJ. MGR.: G.QUARLES	PROJ. NO.: 121205

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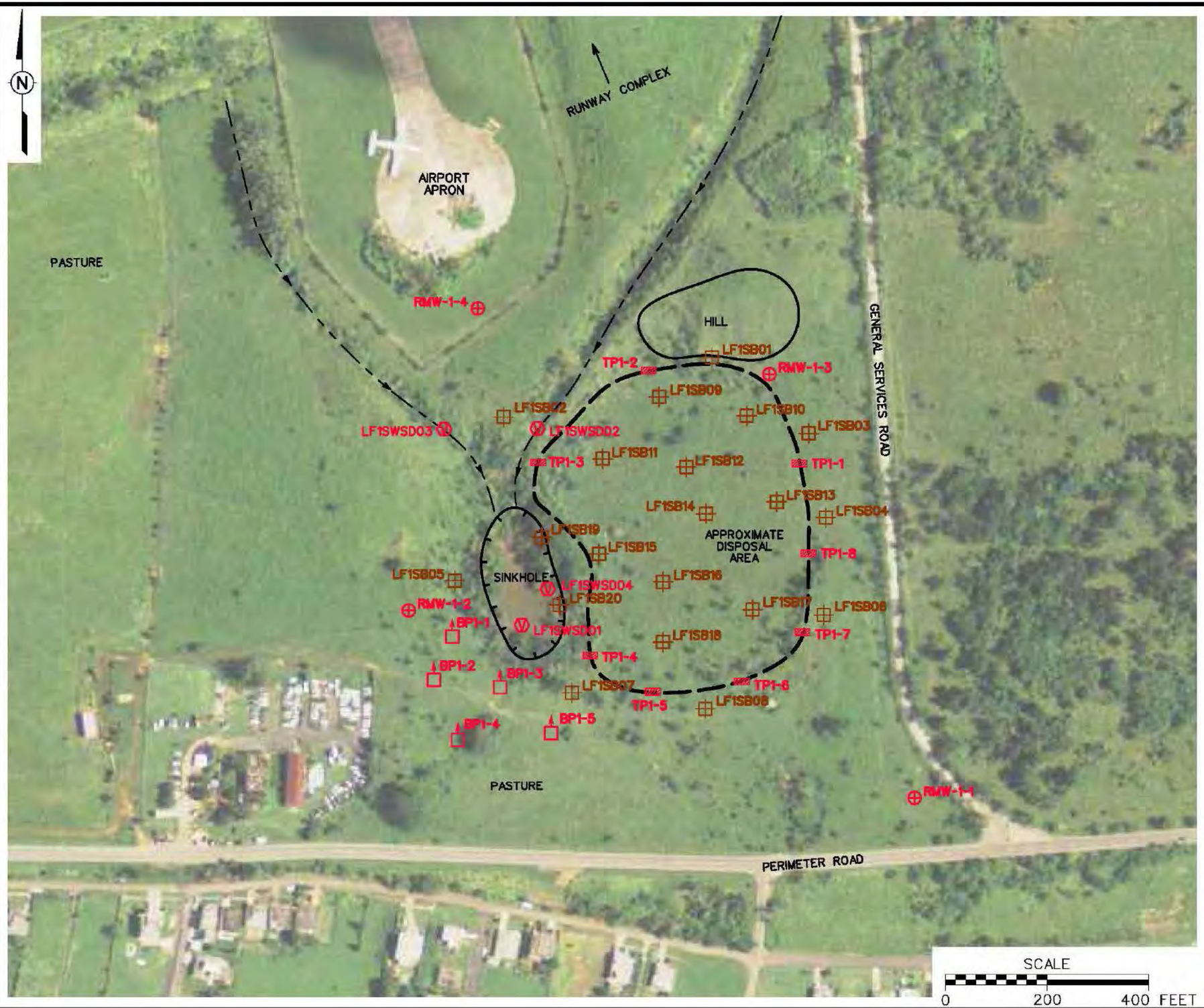

LEGEND

- APPROXIMATE DISPOSAL AREA
- DRAINAGE CHANNEL AND FLOW DIRECTION
- RMW-1-1 — EXISTING MONITORING WELL
- LF1SB05 — PROPOSED SOIL BORING
- LF1SWSD01 — PROPOSED SURFACE WATER/ SEDIMENT SAMPLE LOCATION
- TP1-1 — PROPOSED TEST PIT LOCATION
- BP1-1 — PROPOSED BARHOLE PROBE

NOTES

1. SOIL BORING LOCATIONS LF1SB09 THROUGH LF1SB20 CORRESPOND TO TEST PIT LOCATIONS.
2. SAMPLE LOCATIONS SUBJECT TO CHANGE BASED ON SITE CONDITIONS.
3. BACKGROUND IMAGE OBTAINED FROM SEPT. 21, 2004 ORTHOPHOTO ORIGINALLY DEVELOPED BY THE USACE.

FIGURE 3-1
PROPOSED SAMPLE LOCATION MAP LANDFILL AREA 1

FORMER RAMEY AIR FORCE BASE
AGUADILLA, PUERTO RICO

Shaw Environmental, Inc.

STARTING DATE: 27AUG07	INITIATOR: Z.PARHAM	TECH. REVIEW: K.CUNNINGHAM	DWG. NO.: 121205-lfn2-rlwp-06.dgn
DRAWN BY: C.E.TUMLIN	CADD REVIEW: C.E.TUMLIN	PROJ. MGR.: G.QUARLES	PROJ. NO.: 121205

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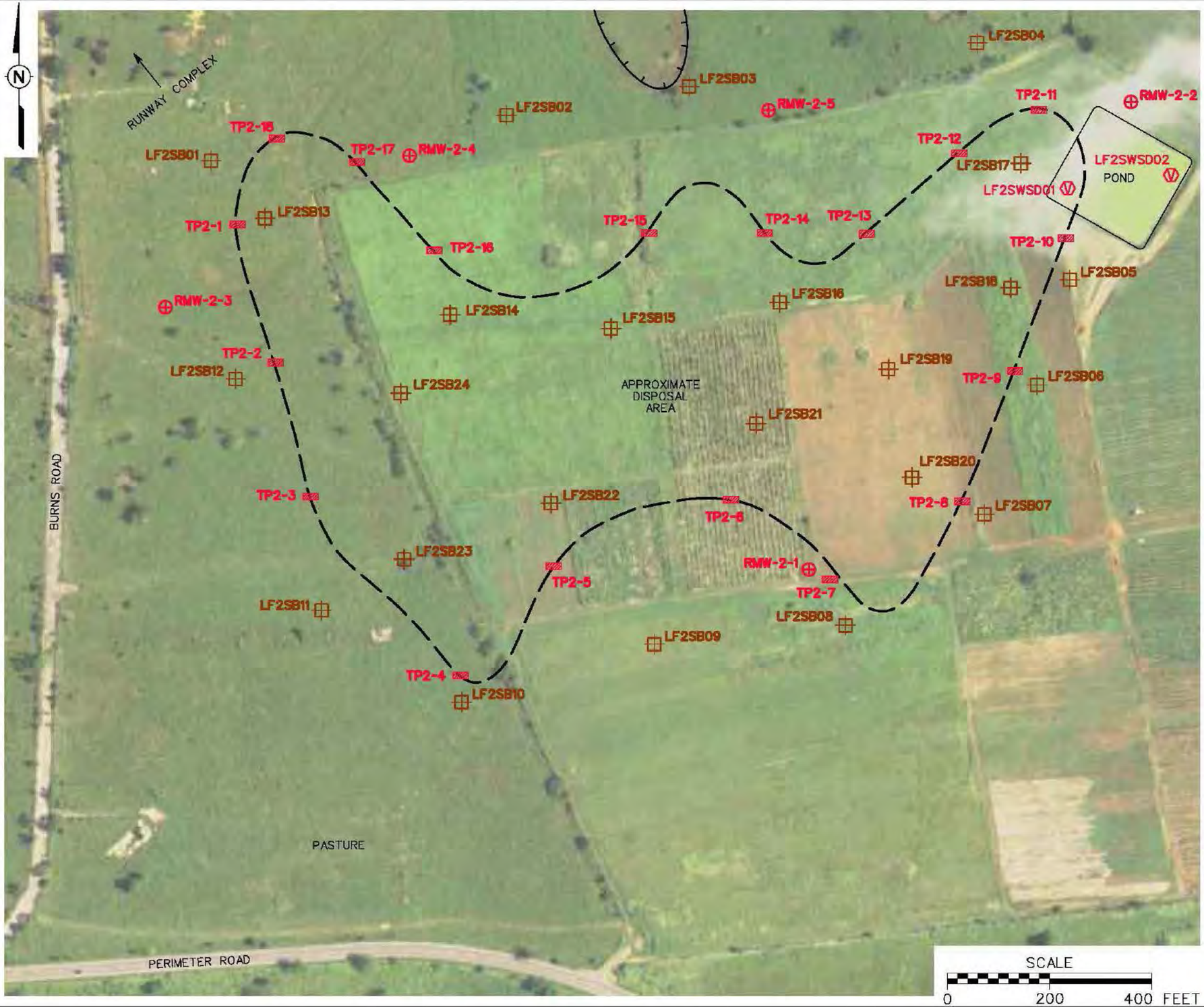

LEGEND

- APPROXIMATE DISPOSAL AREA
- RMW-2-1 — EXISTING MONITORING WELL
- LF2SB05 — PROPOSED SOIL BORING
- LF2SWSD01 — PROPOSED SURFACE WATER/ SEDIMENT SAMPLE LOCATION
- TP2-1 — PROPOSED TEST PIT LOCATION

NOTES

1. SOIL BORING LOCATIONS LF2SB13 THROUGH LF2SB24 CORRESPOND TO TEST PIT LOCATIONS.
2. SAMPLE LOCATIONS SUBJECT TO CHANGE BASED ON SITE CONDITIONS.
3. BACKGROUND IMAGE OBTAINED FROM SEPT. 21, 2004 ORTHOPHOTO ORIGINALLY DEVELOPED BY THE USACE.

SCALE

0 200 400 FEET

Shaw® Shaw Environmental, Inc.

FIGURE 3-2
PROPOSED SAMPLE LOCATION MAP LANDFILL AREA 2

FORMER RAMEY AIR FORCE BASE AGUADILLA, PUERTO RICO

STARTING DATE: 27AUG07 | INITIATOR: Z.PARHAM | TECH. REVIEW: K.CUNNINGHAM | DWG. NO.: 121205-lfh2-rlwp-07.dgn
DRAWN BY: C.E.TUMLIN | CADD REVIEW: C.E.TUMLIN | PROJ. MGR.: G.QUARLES | PROJ. NO.: 121205

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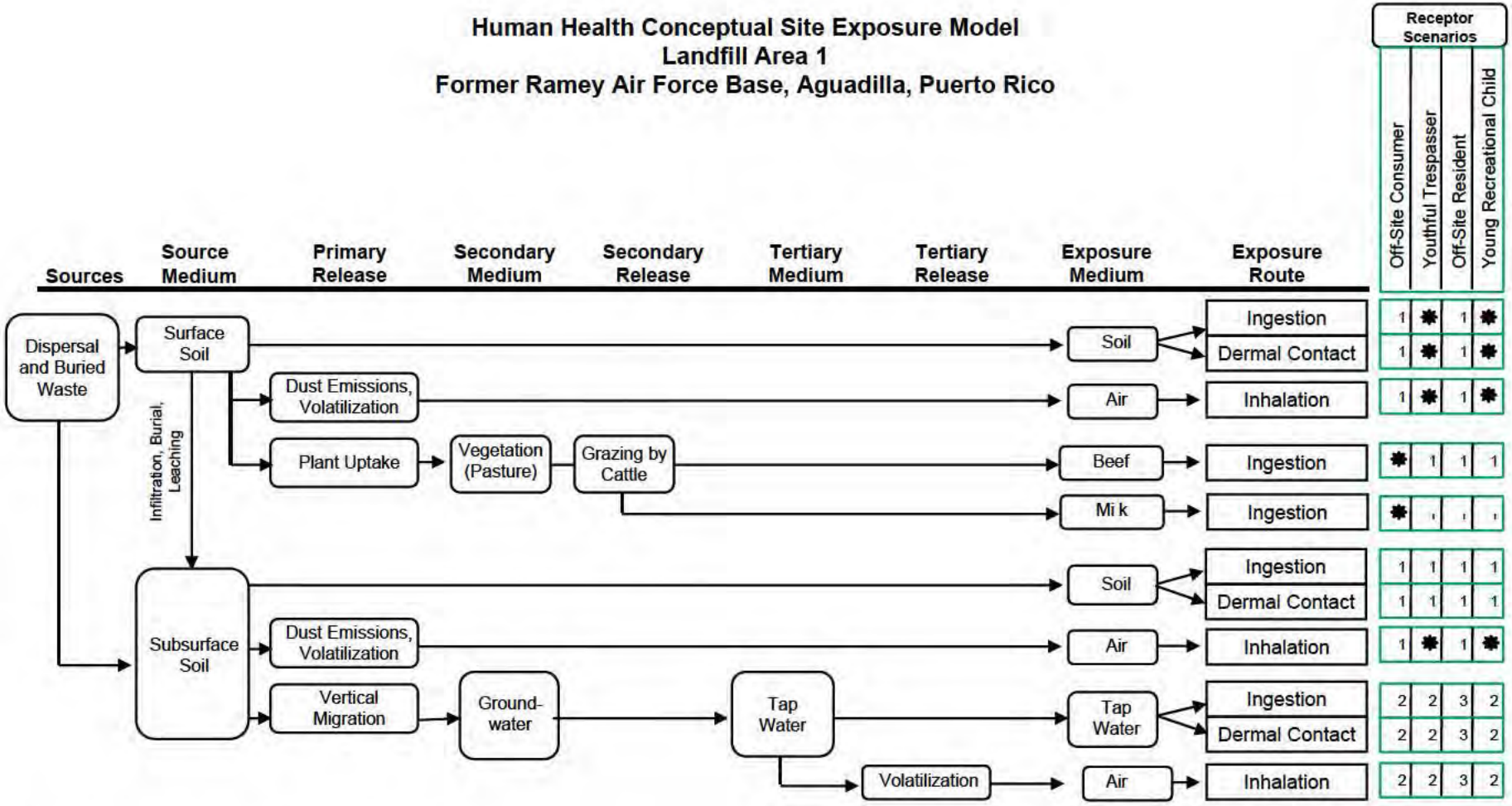
Figure 4-1

Human Health Conceptual Site Exposure Model
Landfill Area 1
Former Ramey Air Force Base, Aguadilla, Puerto Rico

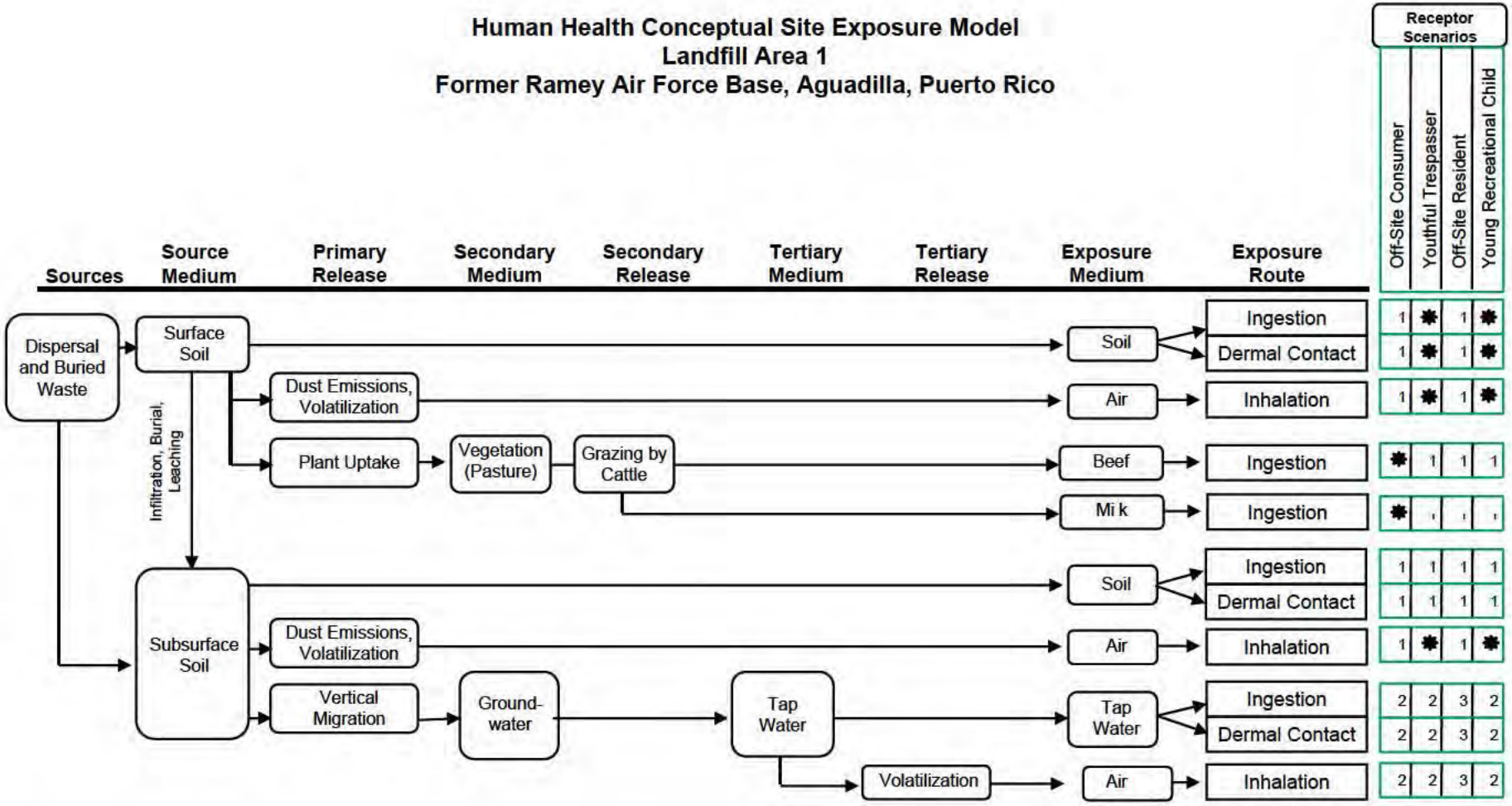


✱ = Complete exposure pathway evaluated in baseline risk assessment
1 = Incomplete exposure pathway.
2 = Implausible groundwater exposure pa hway not evaluated.
3 = Evaluated as complete exposure pathway in the risk assessment; please refer to Section 4.3.1.3 of text.

KN10/RAFB/LF1-2/RIWP/F/Fig4.-1/5-3-10

Figure 4-1

Human Health Conceptual Site Exposure Model
Landfill Area 1
Former Ramey Air Force Base, Aguadilla, Puerto Rico

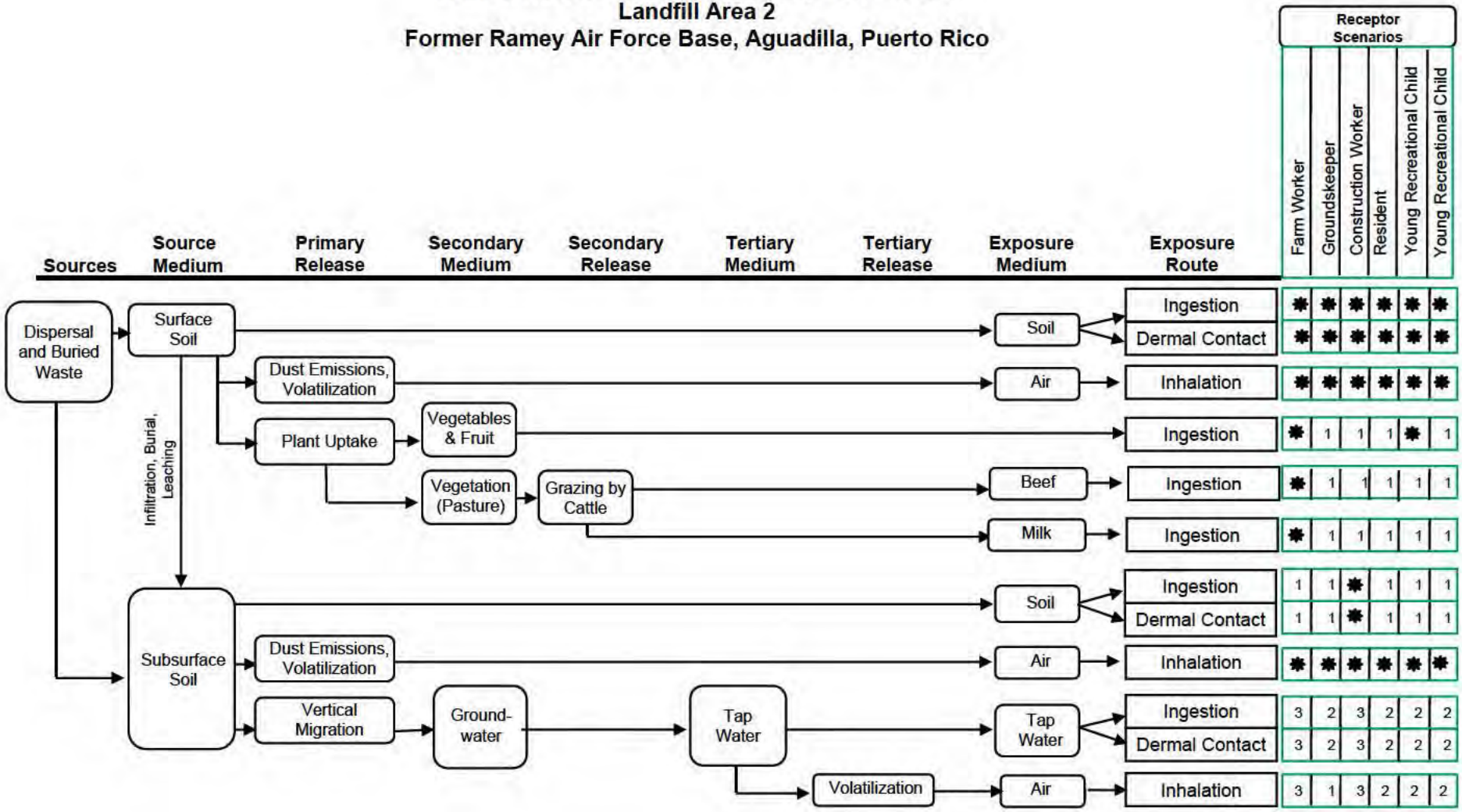


✱ = Complete exposure pathway evaluated in baseline risk assessment
1 = Incomplete exposure pathway.
2 = Implausible groundwater exposure pa hway not evaluated.
3 = Evaluated as complete exposure pathway in the risk assessment; please refer to Section 4.3.1.3 of text.

KN10/RAFB/LF1-2/RIWP/F/Fig4.-1/5-3-10

Figure 4-2

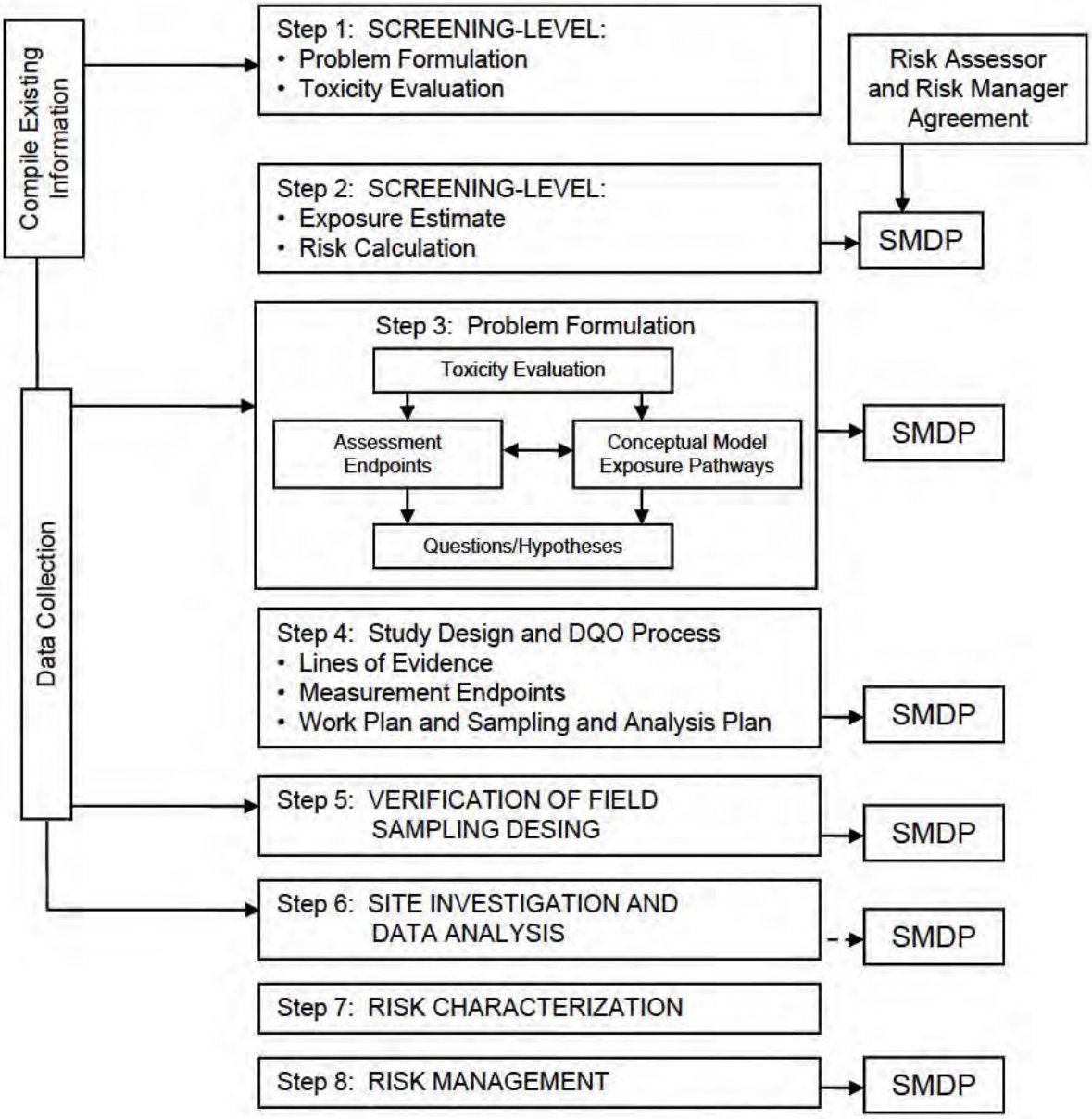
Human Health Conceptual Site Exposure Model
Landfill Area 2
Former Ramey Air Force Base, Aguadilla, Puerto Rico



✱ = Complete exposure pathway evaluated in baseline risk assessment.
1 = Incomplete exposure pathway.
2 = Implausible groundwater exposure pathway not evaluated. In the baseline risk assessment.
3 = Evaluated as complete exposure pathway in the baseline risk assessment; please refer to Section 4.3.1.3 of text.

KN10/RAFB/LF1-2/RIWP/F/Fig4.-2/5-3-10

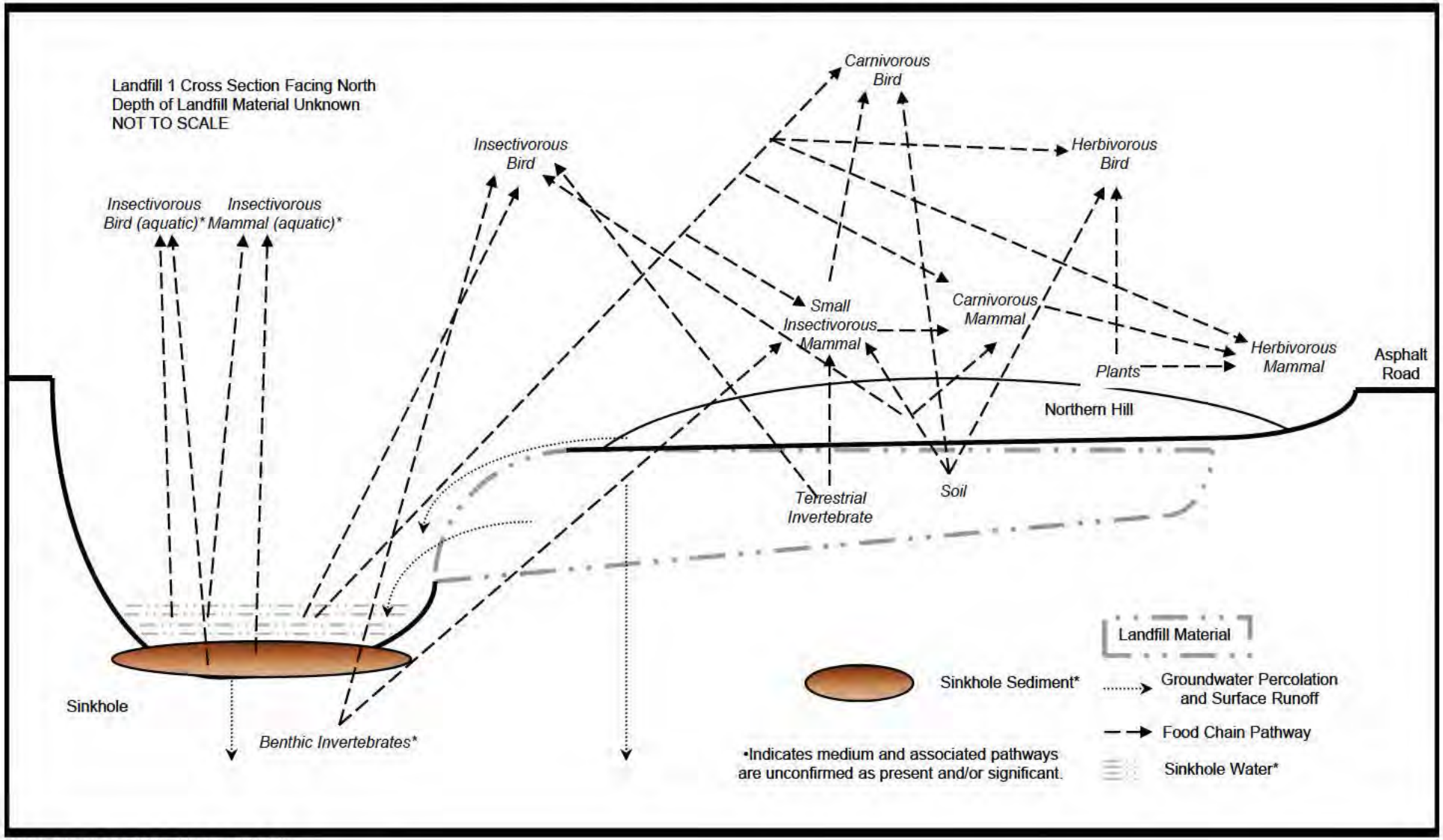
Figure 5-1
Eight-Step Ecological Risk Assessment Process for Superfund



SMDP = Scientific management decision point
Source:
U.S. Environmental Protection Agency (EPA), 1997, Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final, EPA/540/R-97/006.

Figure 5-2

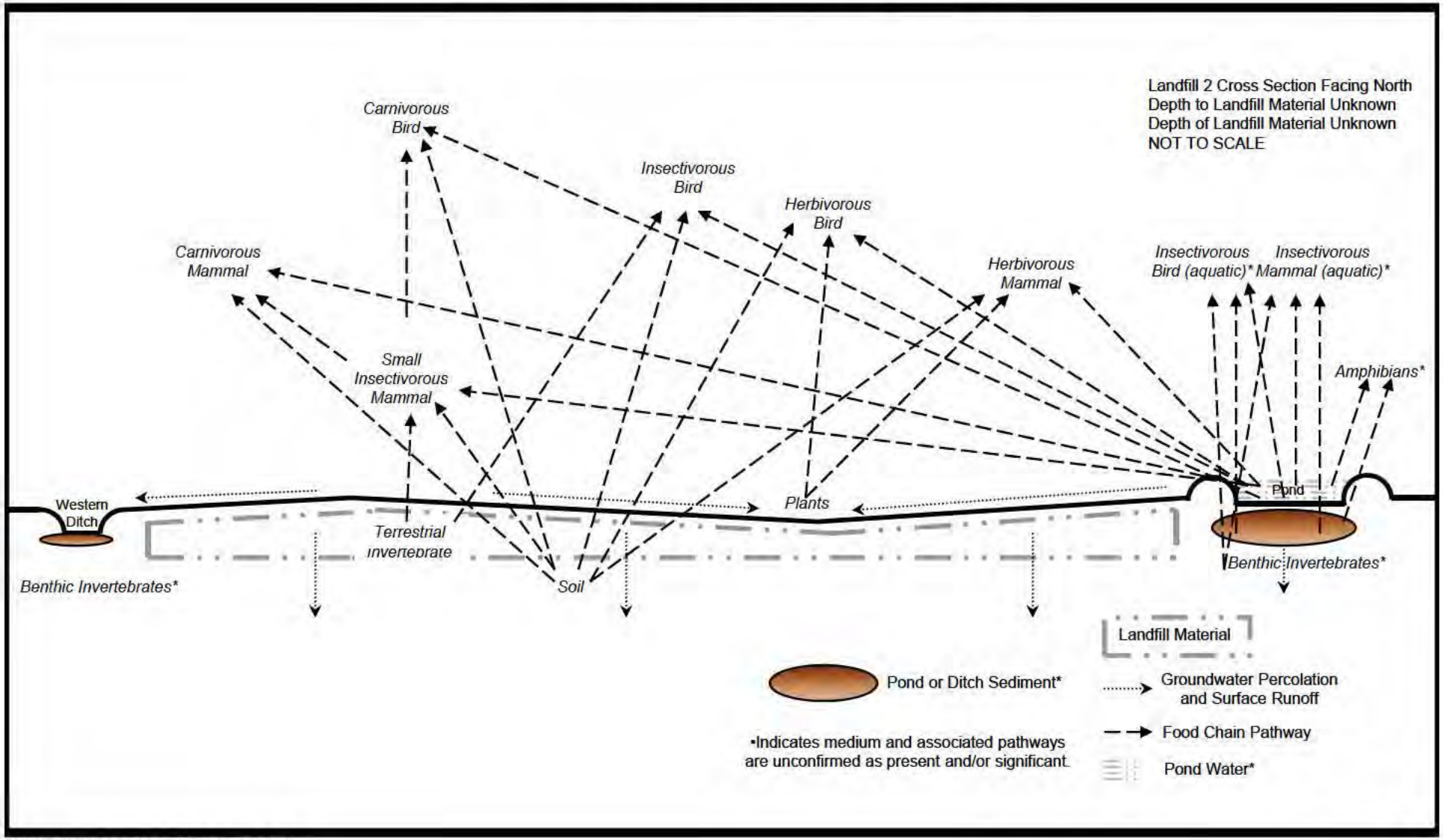
Ecological Conceptual Site Model
Landfill Area 1
Former Ramey Air Force Base, Aguadilla, Puerto Rico



KN10/RAFB/LF1-2/RIWP/F/Fig 5-2.ppt/5-3-10

Figure 5-3

Ecological Conceptual Site Model
Landfill Area 2
Former Ramey Air Force Base, Aguadilla, Puerto Rico



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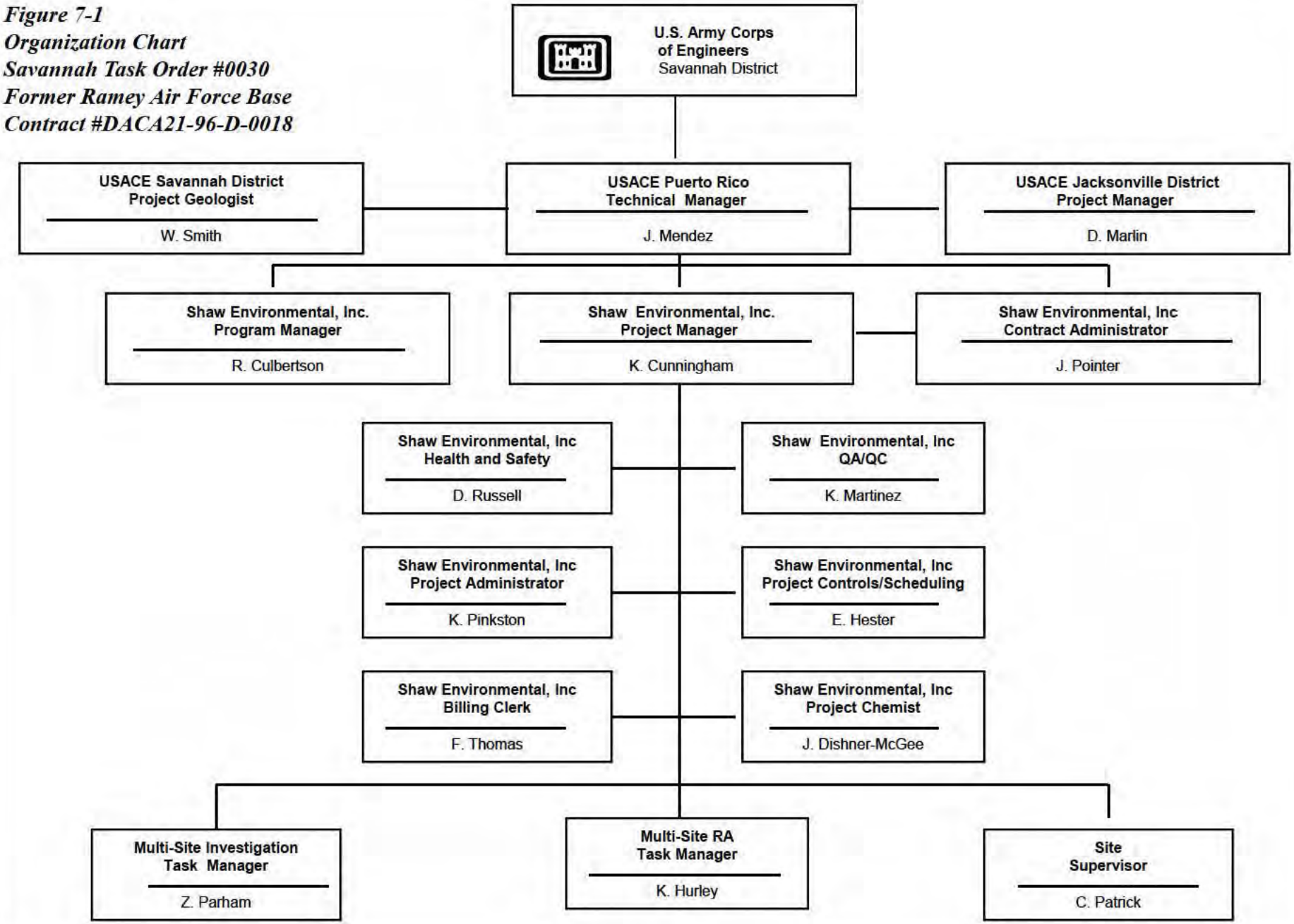
Figure 7-1
Organization Chart
Savannah Task Order #0030
Former Ramey Air Force Base
Contract #DACA21-96-D-0018