RR-00206-03.13-05/15/92

Remedial Investigation/ Feasibility Study for Site 15 Naval Station Roosevelt Roads Puerto Rico

Prepared for

Atlantic Division
Naval Facilities Engineering Command
Norfolk, Virginia

Prepared by

Versar INC.

MAY 15, 1992

RR-00206-03.13-05/15/92

Versar INC

FINAL DRAFT

REMEDIAL INVESTIGATION/FEASIBILITY STUDY FOR SUBSTATION NO. 2 (SITE 15) BUILDING 90, NAVAL STATION ROOSEVELT ROADS, PUERTO RICO

Prepared for:

Atlantic Division
Naval Facilities Engineering Command
Norfolk, Virginia

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May 15, 1992

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EXECUTIVE SUMMARY

Versar performed a Remedial Investigation (RI)/Feasibility Study (FS) to develop viable remedial alternatives for known polychlorinated biphenyl-contaminated (PCB-contaminated) soil and concrete at Site 15, Roosevelt Roads Naval Station, Puerto Rico. This RI/FS was performed according to criteria in the National Contingency Plan (NCP) and guidelines stipulated by the U.S. Environmental Protection Agency (USEPA) in RI/FS guidance documents.

The RI determined that sediment and soil surrounding the immediate area of Substation No. 2 and the transformer pads is contaminated with PCBs at concentrations exceeding ARARs. The depth of contamination is at least 1 foot; however, the presence of coral at a depth of 1 foot prevents deeper sampling at this time. This RI/FS focuses on the soil/sediment operable unit. Any potential contamination of coral, ground-water or surface water pathways are to be evaluated during the initial soil removal action proposed herein. An estimated 235 cubic yards of soil/sediment require remediation.

The FS for Site 15 identified three remedial alternatives that survived screening for all nine CERCLA criteria for evaluating and selecting remedial alternatives: overall protection of human health and the environment; compliance with applicable or relevant and appropriate requirements (ARARs); long-term effectiveness and permanence; short-term effectiveness; reduction of mobility, toxicity, and volume; implementability; cost; local government acceptance; and community acceptance. Those alternatives that survived screening are: Alternative A - soil excavation, shipment, and off-site incineration; Alternative B - soil excavation, shipment, and off-site landfill; and Alternative C - soil excavation, and on-site incineration.

Other alternatives were eliminated from consideration for the following reasons: technology not proven at or near full scale; technology not feasible; technology not applicable, not demonstrated, or not commercially available for testing or destroying PCB solid waste; or technology potentially applicable, but requires and successful laboratory or pilot field tests to demonstrate viability.

The remedial technology recommended for Site 15 is Alternative B - soil excavation, shipment, and off-site landfill. There are no incineration or landfill facilities licensed to accept PCB wastes located in Puerto Rico. The U.S. Ecology-Beaty, Nevada facility is the nearest approved facility for disposal of PCB-bearing materials generated by remedial action at Site 15. The long-term potential liabilities associated with landfill disposal are higher than incineration, but are offset greatly by the low cost of landfill disposal. This process option was selected based on probable achievement of the nine CERCLA criteria for selecting remedial alternatives. The cost for this alternative at this site is estimated to be $426,621.

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1.0 INTRODUCTION

Versar, Inc. has been contracted (Navy Contract No. N62470-90-B-7645) by the U.S. Navy Facilities Engineering Command (NAVFACENGCOM), Atlantic Division (LANTDIV), to perform a follow-up Remedial Investigation and Feasibility Study (RI/FS) in order to complete the RI/FS efforts for Substation No. 2, Building 90 (Site 15) identified in the Initial Assessment Study at Naval Station (NAVSTA) Roosevelt Roads, Puerto Rico. Work Plan, Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), and Health and Safety (HSP) were prepared to describe the available environmental information concerning the site, detail the tasks required to complete the RI/FS efforts, and the manner in which they were to be accomplished and managed. These work plans were subsequently reviewed and approved for use by NAVSTA Roosevelt Roads and LANTDIV environmental staff, and by the Naval Energy and Environmental Support Activity (NEESA) contractor, Martin Marietta for adherence to NEESA quality assurance requirements.

This RI/FS report has been prepared using the latest guidance (EPA, 1988a) and contains the results of the field investigation and sampling, a site characterization, risk assessment, and feasibility study for the site. All data collected during the May 1991 sampling activities were analyzed according to U.S. Environmental Protection Agency (EPA) Contract Laboratory, Program (CLP) methods developed for the EPA's Superfund Program. These data were then validated according to full EPA data validation procedures as specified in EPA (1988b). The chain of custody documents and data validation reports are contained in Appendix A. Previous data contained in the "Remedial Action Alternatives Analysis" for Site 15 (ESE, 1988) and Confirmation Study were not validated and are used for site characterization purposes only.

1.1 Purpose of the Report

The RI/FS report for Site 15, Substation no. 2, Building 90 is intended to summarize existing site conditions, characterize the nature and extent of risks posed by the site, and provide the necessary and sufficient information for evaluating potential remedial options for contaminated media at the site. Ultimately, the goal of the RI/FS for this site is to select a remedy that is protective of human health and the environment, that maintains this protection over time, and that minimizes untreated wastes.

In order to speed the selection of an appropriated remedy for the site, this RI/FS focuses on the contaminated soil and sediment media at the site. The emphasis has been placed on the soil/sediment and building/concrete exterior, operable units in consideration of the special characteristics of polychlorinated biphenyl (PCB) contaminants. PCBs have

applicable or relevant and appropriate requirements (ARARs) that are addressed by both Toxic Substances Control Act (TSCA) and Resource Conservation and Recovery Act (RCRA) and whose remedial action levels are largely defined in terms of solid media owing to the relatively immobile nature of PCBs in aqueous media. Additionally, contamination of soil, sediment and exteriors of buildings or concrete structures are the most clear and direct routes of human exposure present at the site.

1.2 Site Background

NAVSTA Roosevelt roads is located on the east coast of Puerto Rico in the municipality of Ceiba, approximately 33 miles southeast of the capital city of San Juan (Figure 1). It is bordered on all sides, but the west by the Caribbean Sea. Located to the southwest is agricultural land use and Bosque Estatal de Ceiba, a mangrove forest adjacent to the station's western border (Greenleaf/Telesca, 1984). Immediately to the west of the station and adjacent to its western border is the town of Ceiba. The nearest major town is Fajardo located 10 miles north of the station.

The town of Ceiba is located near the station's western boundary. It has the largest population in the vicinity of the station, with 15,000 people in an area of approximately 27.5 square miles.

This RI/FS report addresses Substation 2, Building 90 (Site 15) on the base (Figure 2). A preliminary assessment (initial assessment study [IAS] under the Navy's older NACIP terminology) has been completed for NAVSTA Roosevelt Roads, including Substation No. 2. A site investigation (called a confirmation study under the NACIP terminology) was also conducted. The preliminary assessment and site investigation (PA/SI) indicated PCBs present in soil at concentrations exceeding ARARs, and partially delineated the extent of soil contamination.

1.2.1 Site Description and History

The primary mission of NAVSTA Roosevelt Roads is to provide full support for Atlantic Fleet weapons training and development activities. Site 15 is under the jurisdiction of the Power Distribution Shop. The Power Distribution Shop maintains and repairs the electrical distribution system for NAVSTA Roosevelt Roads. This department is responsible for maintenance and servicing of electrical transformers of over 600 volt rating and maintains 13 main transformers in eight substations located at the airfield, industrial areas, Bundy area, and the Capehart Housing area.

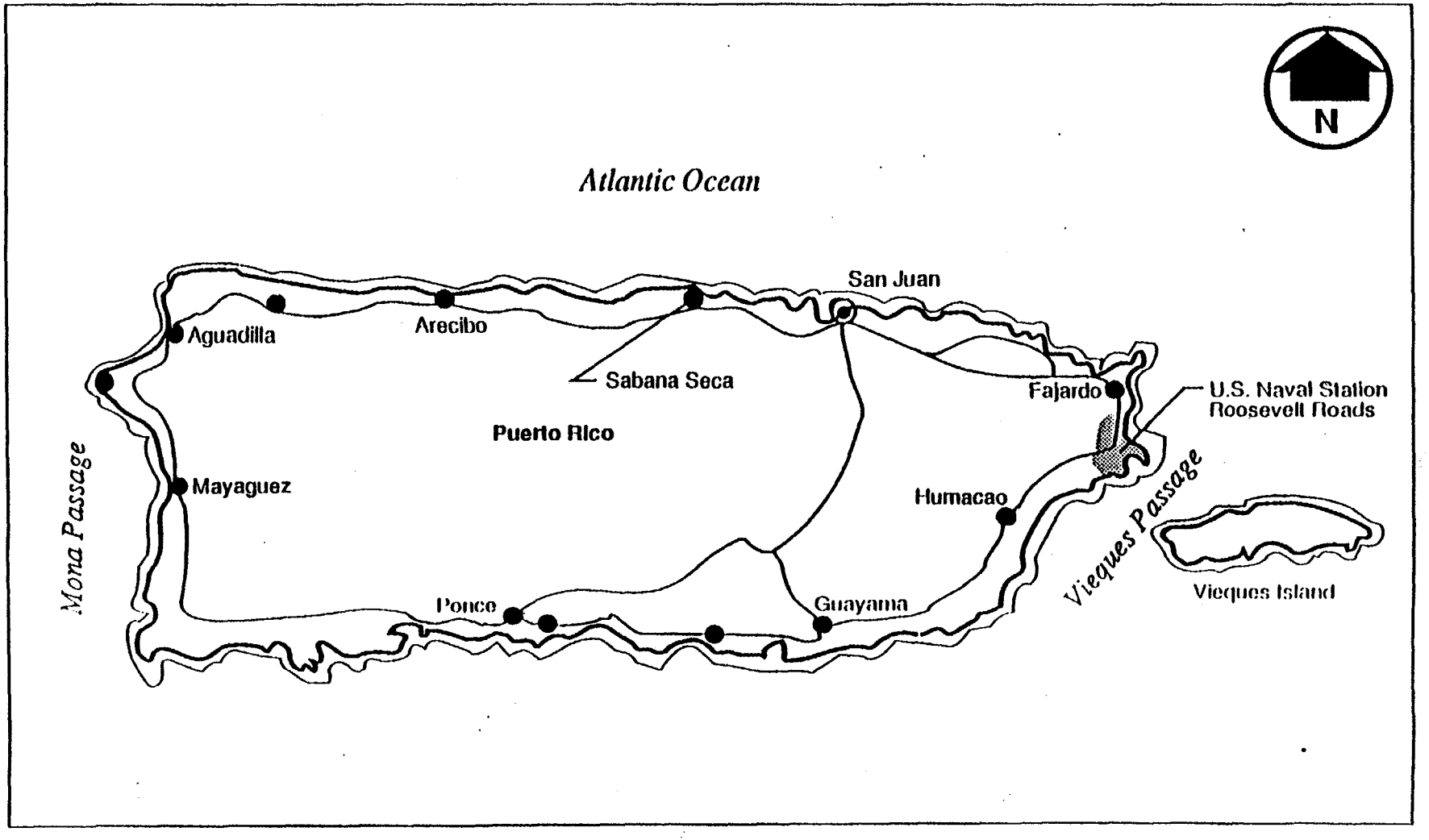

FIGURE 1
LOCATION OF NAVSTA ROOSEVELT ROADS, PUERTO RICO

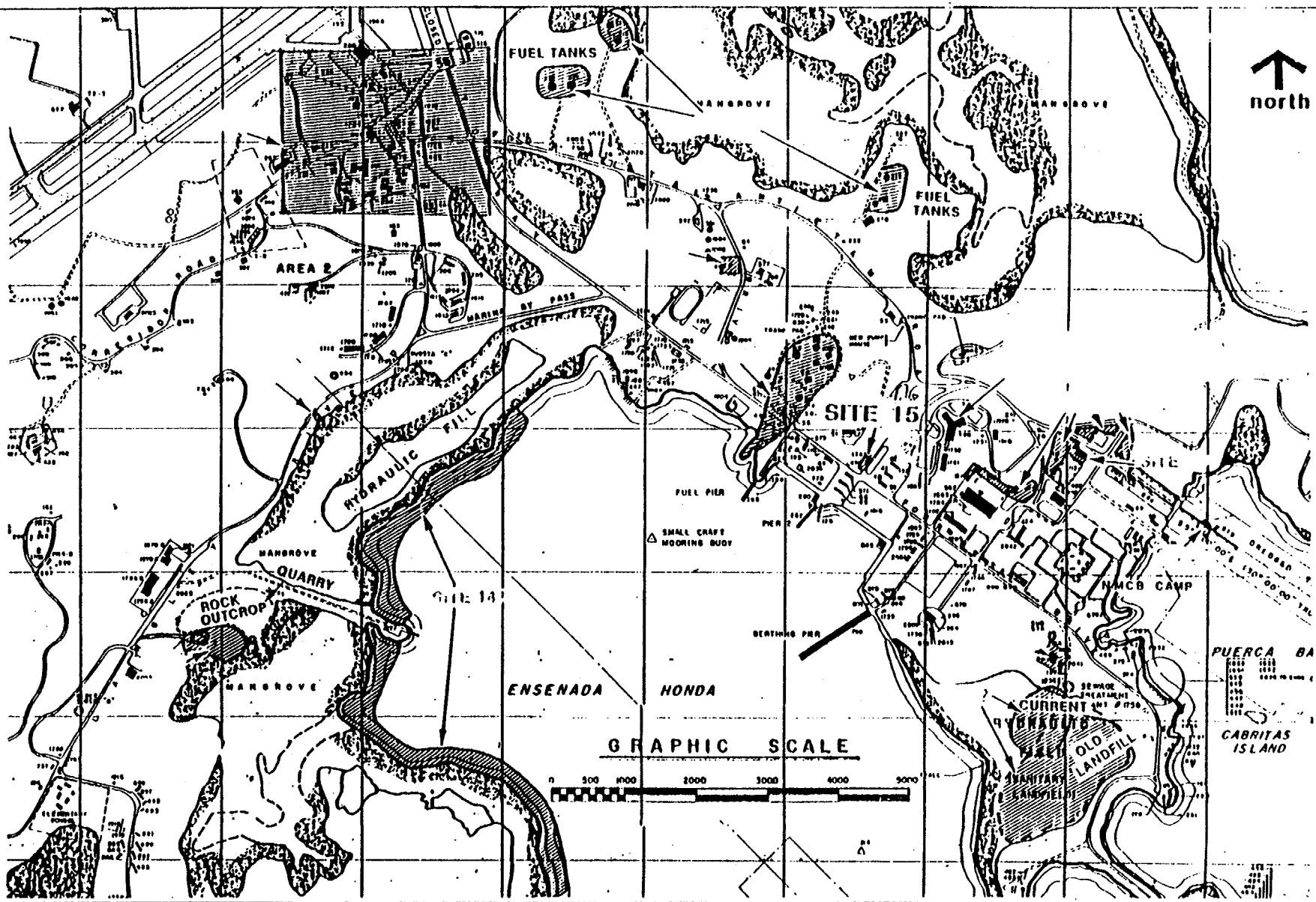

FIGURE 2 LOCATION OF SITE 15
NAVSTA ROOSEVELT ROADS

U.S. NAVAL COMPLEX
PUERTO RICO

RR-00206-03.13-05/15/92

Elevations on the base range from sea level to 1,050 feet above sea level, with the tallest peak located within 2 kilometers of the station's boundary. The station is located over an area with hills and valleys of the coastal plain extending from the Sierra de Luquillo range. In the low-lying shore area, seawater flooding results from storms, wind, and abnormally high tides. The region has a humid, tropical climate, moderate temperatures, dense vegetation, and high rainfall.

From 1964 to the present, the Power Distribution Shop has maintained and repaired transformers at Substation No. 2, Building 90. As part of maintenance of the transformers, the transformer oil was drained to facilitate repair to the inner cores and coils. During 1964 to 1979, it was routine practice to drain or pour the transformer oil onto the ground at the work location. It is estimated that a maximum of 3,000 gallons of PCB-contaminated transformer oil was disposed of on the ground at the site during that period of time.

Contamination migration from Site 15 could potentially occur by surface runoff and soil erosion through two drainage ditches (Figure 3). Surface runoff would occur from the series of drainage ditches which empty into the Rio Daguao watershed into the mangroves that fringe Ensenada Honda (Figures 1, 2, 3). Most of what is known of the nature of contamination was gleaned through the PA/SI conducted for the site.

1.2.2 Previous Investigations

Substation No. 2 (Site 15) was the subject of an IAS performed by Greenleaf/Telesca (1984). The IAS began with a records search at various government agencies, including the base and NAVFACENGCOM, national and regional archives and records centers, and U.S. Geological Survey offices. In this initial step, study team members reviewed records to assimilate information about the activity's mission, industrial processes, waste disposal records, and known environmental contamination. Typical examples of records include activity master plans and histories, environmental impact statements, historical records, and aerial photographs.

After the records search, the study team conducted an on-site survey to complete documentation of past operations and disposal practices and to identify potentially contaminated areas. With the assistance of an activity point of contact, the team inspected the activity during ground and aerial tours, and interviewed long-term employees and retirees.

The on-site survey for NAVSTA Roosevelt Roads was conducted from January 15 to February 10, 1984. Based on the information provided in the IAS Report, a Confirmation

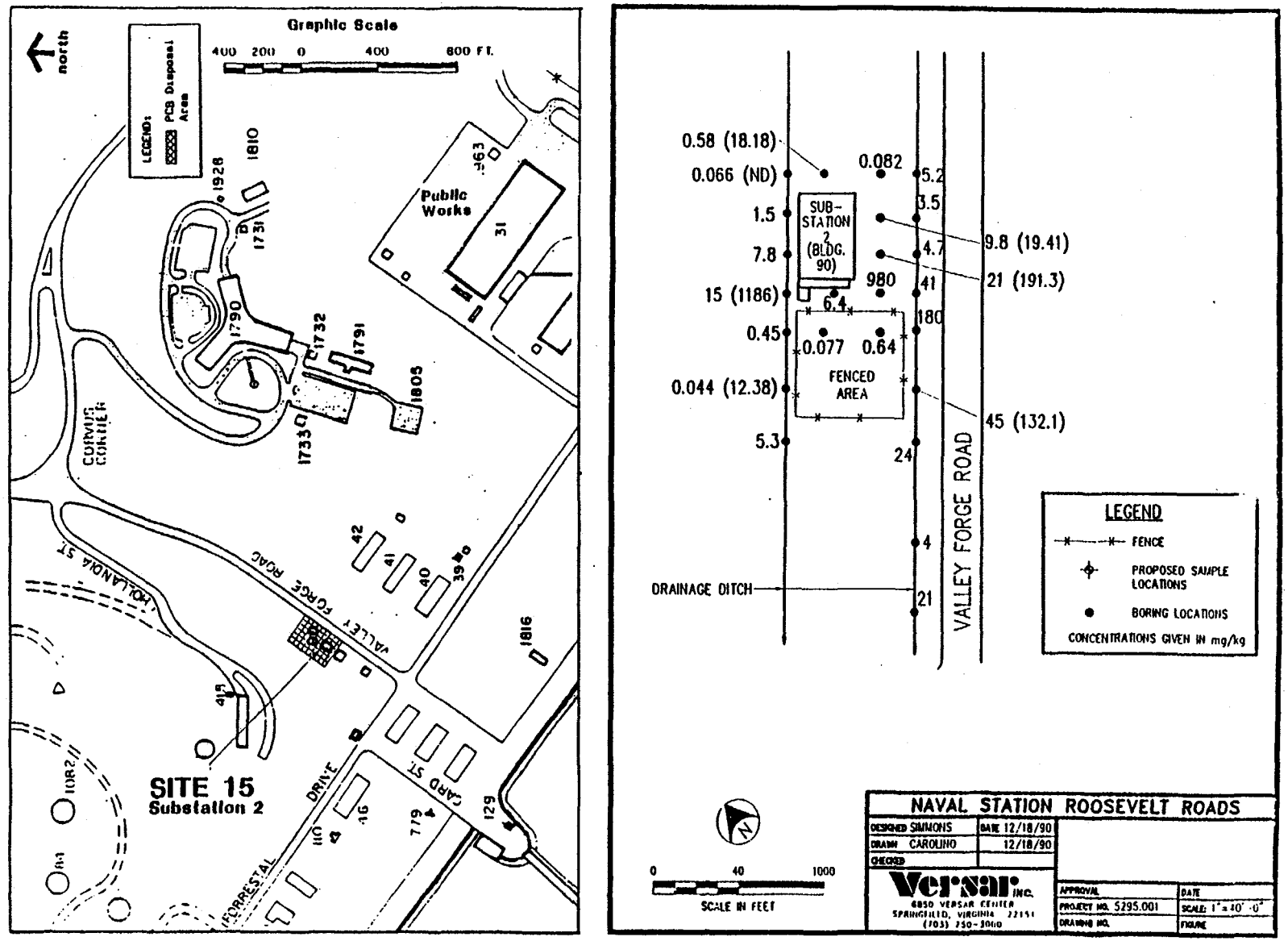

FIGURE 3
LOCATION AND CONFIRMATION STUDY SAMPLING LOCATIONS FOR
SITE 15: SUBSTATION NO. 2, BUILDING 90,
NAVSTA ROOSEVELT ROADS, PUERTO RICO

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Study (SI, under Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] terminology) was performed for Substation 2 (Site 15). A Confirmation Study is typically divided into verification and characterization phases and is recommended only for sites at which (1) sufficient evidence exists to indicate the presence of contamination, and (2) the contamination poses a potential threat to human health or to the environment.

As part of the Confirmation Study, thirty-six soil samples were collected from 33 had augered soil borings at Site 15. Soil samples were collected from the surface to a depth of 1 foot below land surface (BLS) in all but two of the borings which were extended deeper. The soil samples were analyzed for PCBs. Concentrations of PCBs ranged from not detected (ND) to 1,186 parts per million (ppm). The sample locations and results are shown on Figure 3. PCB levels above 50 ppm were found at four sampling locations. The highest concentrations were found around Building 90 and in the drainage ditch along Valley Forge Road. Two samples from the fenced-in storage yard were <1 ppm. The sample results and locations were presented in a report entitled Remedial Action Alternatives Analysis for Substation 2, Site 15, USNAVSTA Roosevelt Roads, Environmental Science and Engineering, Inc., February 1988. The full text of the ESE (1988) report is contained in Appendix B. No remedial actions have been performed at Site 15 to date.

The preliminary risk assessment found that the worst case scenario involves dermal absorption, incidental ingestion, and inhalation of dust. The calculated Pathway Preliminary Pollutant Limit Value (PPLV) for PCBs is 20 mg/kg. Therefore, based on the (ESE, 1988) site-specific risk assessment, the calculated PCB clean-up level was 20 mg/kg or ppm. However, the more conservative TSCA clean-up standard of 10 ppm was used by ESE in their development of preliminary remedial alternatives to provide an added degree of protection of human health.

ESE (1988) proposed four preliminary remedial alternatives for Site 15. The four alternatives vary in degree of addressing the PCB contamination at the site. The remedial action alternatives for each site will be discussed in this section. The sampling proposed in the current RI/FS was designed to supplement the ESE data base, and aid in determining volume requirements to meet the objectives of Alternative 4 (excavation and disposal).

Remedial Action Alternatives for Site 15 identified by ESE (1988) are as follows:

Alternative 1: The "no action alternative". A 6-foot high galvanized chain link fence would be installed surrounding all areas of the site confirmed to have PCB concentrations above 10 ppm.

Alternative 2: A single-layered asphalt cap would be installed over the site. The cap would consist of 4 inches of base material and 1 inch of bituminous paving. The cap would cover those areas of the site confirmed to have PCB concentrations of 10 ppm or more.

Alternative 3: Both partial capping and excavation would occur. All areas of the site confirmed to have PCB concentrations above 25 ppm would be excavated. This would be removed to a depth of 1 foot. The excavated areas would then be backfilled with clean soil. Clean soil is defined by EPA as containing less than 1 ppm PCBs. Site areas confirmed to have PCB concentrations of 10 to 25 ppm would be capped with a single-layer asphalt cap. The cap would meet the same specifications as in Alternative 2. Excavated material would be disposed of by incineration in an incinerator permitted for PCB incineration.

Alternative 4: The most stringent of the four in meeting PCB cleanup criteria. All site areas confirmed to have PCB concentrations exceeding 10 ppm would be excavated. The excavated area would then be backfilled with clean soil. Excavated material would be disposed of by incineration.

Each media specific alternative proposed by ESE (1988) is included in the current RI/FS report as a process option. However, the FS section of this RI/FS report follows the FS screening process prescribed in the EPA (1988) RI/FS guidance and results in slightly differed assembled remedial alternatives.

1.3 Report Organization

This RI/FS report contains a site characterization of the soil, sediment and exterior surfaces of Site 15. Soil and sediment can be considered a single operable unit at this site. The drainage ditches in which the sediments are found are normally not filled with water. These ditches are more properly considered drainage swales. The beds of these swales are grass-lined and continuous with the surrounding lawn.

Sediments in these drainage swales are differentiated from soil due to the potential for contaminated particulates to be transported by water through the bases storm sewer system. By examining the data in this summer, sediment ARARs can be used to assess whether further investigation of the storm system is warranted.

The building exterior operable unit was investigated using worst-case sampling locations to determine whole building decontamination requirements. Because the building and

concrete surfaces are relatively small at Site 15, unacceptable levels of contaminants would trigger a full decontamination of the entire exterior surface.

The building interiors, ground water, and surface water operable units were specifically not addressed by this RI/FS. Because the substation is currently in use, the building interiors are an occupational exposure (if contaminants are present) and the building is secure from the general public at all times. Therefore, investigation of the interior surfaces may be conducted at another time without affecting the selection of remedy for soil/sediment, or exterior surfaces.

Surface water and ground-water investigations have also been excluded from discussion at the present. The potential for contamination of either of these media can be more reliably assessed following scraping of the site and initial soil removal actions required by TSCA. Soil removal activities will expose the white coral located immediately below the thin soils, making the areas where contaminants could percolate to the water table more apparent. The IAS (Greenleaf/Telesca, 1984) indicates that the ground water at NAVSTA Roosevelt Roads is saline. Therefore, the ground water at the site would be classified as a Class III aquifer under EPA's (1986) ground-water classification guidance. Surface water is not normally present on site except for brief periods immediately after heavy rains. Neither the ground water or surface water operable units are a direct source of human exposure. Selection of remedy for the soil/sediment operable unit does not interface with any future remedial actions for the ground water/surface water operable unit, and will facilitate the assessment nature and extent of contamination of the aqueous media (if any).

Data from the site characterization and evaluation of potential exposure pathways are used to evaluate site risks for current and potential future exposure scenarios. This report also contains a FS that screens potentially applicable remedial process options to arrive at assembled remedial alternatives to eliminate site risks. The scope of the selection of remedy for the FS is limited to the soil/sediment and building exterior operable unit only. The remedial alternatives are intended to define the first phase of remediation and to select the most cost-effective remedy to best protect human health and the environment. Confirmatory sampling, and additional characterization requirements/removal are acknowledged as an integral part of the site remedy and are to be included in the Remedial Action Plan (RAP) to be prepared for this site at a later date.

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2.0 STUDY AREA INVESTIGATION

Site 15 was identified as an area of concern regarding PCB contamination in the IAS. The RI/FS included field activities to assess the extent of this contamination. These activities included confirmatory sampling and sampling from areas not previously evaluated, and was conducted in order to provide thorough and representative analytical results. These analytical results are used to perform a risk assessment, and to delineate the extent of contamination for future remedial activities.

The sampling rationale for the RI/FS at Site 15 was to utilize the ESE data (ESE 1988) to the greatest degree possible in project scoping and remedial design, while supplementing this information with fully validated data that can be used for tasks that require the highest level of data quality, specifically, the risk assessment. As invalidated data, the highest level of use for the ESE (1988) data are screening and engineering purposes.

A major thrust of the soil sampling program had been to attempt to identify deeper areas where PCB-bearing fluids may have percolated to coral. However, the soil at Site 15 is a mixture of white and dark sands which is difficult to visually assess. Also, coral was encountered at depths of less than a foot; all but eliminating the possibility of horizontally stratified sampling. It will be necessary to scrape all of the soil from the site before the degree of coral contamination can be reliably assessed. The soil sampling program recognized the potential for contaminated soil to be transported by wind or water short distances from the actual spill area. Also, additional exposure pathways, such as the drainage ditches were further evaluated. Concrete bulk and wipe samples were intended to identify decontamination needs for concrete surface areas.

2.1 Surface Features

As part of the RI field activities, the important surficial features of Site 15 were mapped by Versar. These features include all concrete areas, fenced areas, utility poles, and storm drains located on site. The dimensions of the site and pertinent structures were measured in the field and used to field check and update the ESE (1988) maps. Additionally, important physical characteristics of the site including the location of the hillside and roads bounding the site, locations of trees, the presence or absence of vegetation, nature of the substrate and flow directions of drainage ditches were also mapped (see Figure 4).

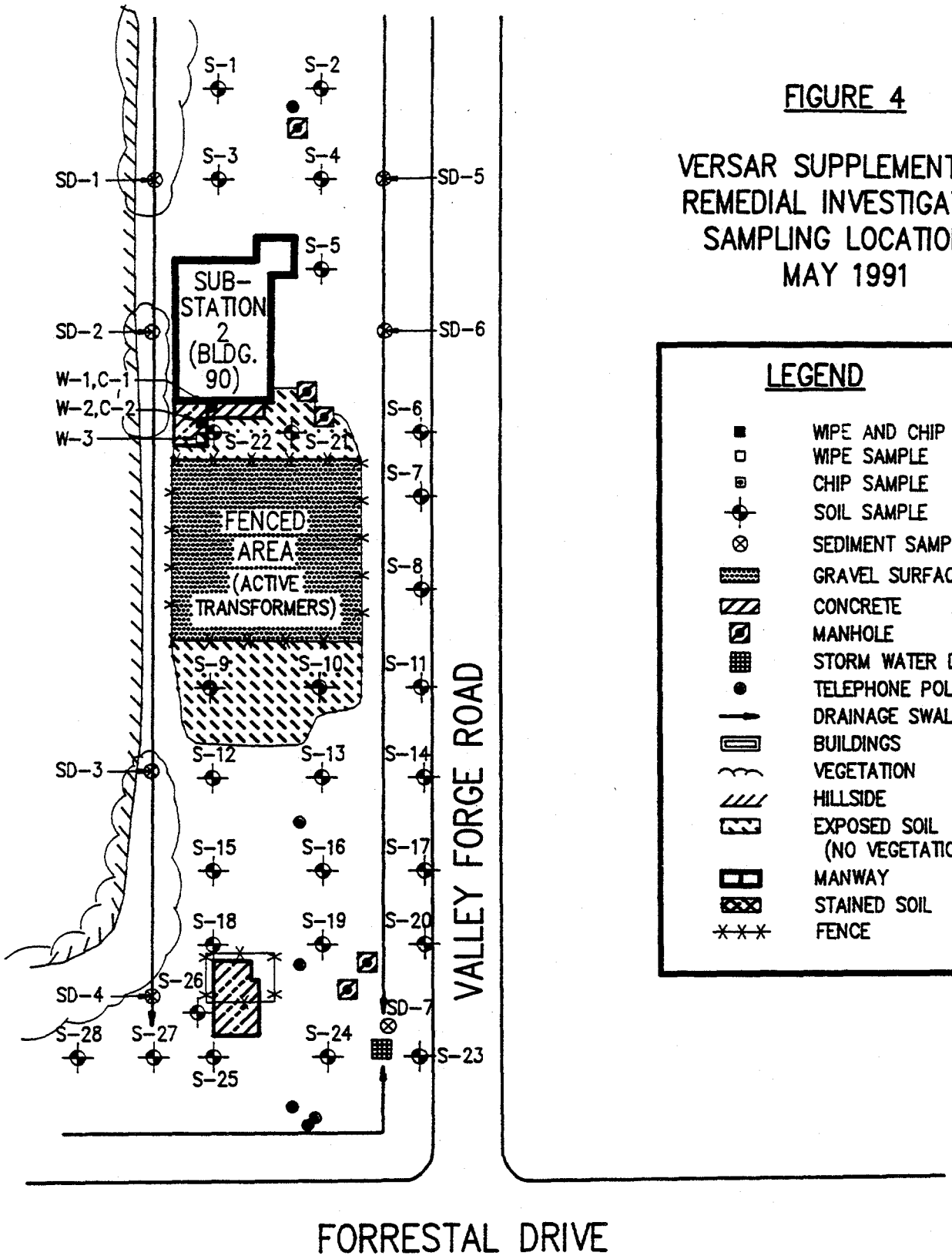

FIGURE 4

VERSAR SUPPLEMENTARY REMEDIAL INVESTIGATION SAMPLING LOCATIONS MAY 1991

LEGEND

- WIPE AND CHIP SAMPLE
- WIPE SAMPLE
- CHIP SAMPLE
- SOIL SAMPLE
- SEDIMENT SAMPLE
- GRAVEL SURFACE
- CONCRETE
- MANHOLE
- STORM WATER DRAIN
- TELEPHONE POLE
- DRAINAGE SWALE
- BUILDINGS
- VEGETATION
- HILLSIDE
- EXPOSED SOIL (NO VEGETATION)
- MANWAY
- STAINED SOIL
- FENCE

N

0 40 100

SCALE IN FEET

D:\5295\004\FIG23A-X.DWG

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2.2 Contamination Source Investigation

A total of 36 additional soil samples were collected to confirm previous analyses for PCB contamination and to further delineate the contaminated area. The sample locations are shown on Figure 4. These samples were largely collected from shallow (0 to 3 inches) soil. Deeper (8 to 12 inches) soil samples were also collected, where possible. Coral outcrops are visible at the site and the soil is less than a foot thick throughout most of the site. Twelve sediment samples were collected from seven locations in the two ditches running along the margins of Substation 2. Deeper soil (8 to 12 inches) was also collected from below the seven drainage ditch sediment sample locations, where possible.

The two concrete chip samples and three wipe samples were collected from the concrete pad at the entrance to Substation 2 to confirm suspected PCB contamination. Wipe and chip samples were used to characterize the unstained concrete surfaces to determine potential needs for remediation of these structures.

Precleaned, dedicated stainless steel scoops were used to collect the soil and sediment samples. The soil or sediment was scooped from the earth and placed in aluminum pie pans for compositing. A clean pie pan was used and a fresh pair of PVC gloves was worn by the sampler for each sample. The sample was thoroughly homogenized using the stainless steel scoop, and the sample volume reduced to the appropriate aliquot using the cone and quarter technique. The sample was then placed in a precleaned I-Chem (or equivalent) 8-ounce glass sample container and held on ice under drain of custody.

Concrete chips were collected using a bush hammer and chisel to pulverize the concrete surface to a depth of 1/4 to 1/2 inches deep. The hammer and chisel were decontaminated using a methanol, hexane, and distilled water rinse between each sampling location. Nitrile gloves and a stainless steel spatula were used to place the sample into precleaned sample jars. Wipe samples were collected by first using a 0.25m^2-template to delineate the sample area. A fresh pair of polyvinyl chloride (PVC) gloves were worn at each sampling location. A sterile gauze pad was then wetted with 8 ml of hexane. Due to the high daily temperatures, it was sometimes necessary to rewet the pad with hexane. Even and steady pressure to the pad was applied while drawing it in straight strokes from the left to the right in slightly overlapping, adjacent strokes. Following completion of the left to right wiping, the procedure was repeated from bottom to top of the wipe area. The gauze pad was then folded back onto itself twice and placed into a precleaned 8-ounce glass sampling container.

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All samples collected at Site 15 were held in a cooler with ice under strict chain of custody procedures. Samples were shipped via overnight air express to Versar's laboratory in Springfield, Virginia, for analysis. All samples were analyzed according to current Contract Laboratory Program (CLP) protocols.

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3.0 PHYSICAL CHARACTERISTIC OF THE STUDY AREA

Site 15 consists of Substation no. 2, Building 90, and two fenced in transformer areas located in a narrow strip of grass between Valley Forge Road and a steep hillside with rock outcrops that parallels Valley Forge Road. The site is largely covered by a well maintained lawn, except within and near the larger transformer area. The area surrounding the transformers within this fenced area is gravel, and there is little vegetation between this area and Substation no. 2, or south of the fence line (Figure 4). Coral and volcanic bedrock can be seen protruding in these unvegetated areas and the sandy soil profile is excessively thin and poorly developed, therefore, the lack of vegetation in these areas may not be directly the result of contamination.

Notably stained soil was noted near the southern transformer pad. This transformer is set on a concrete pad, which protrudes from below the fence (Figure 4). Several telephone/utility poles traverse the site from northeast to southwest, parallel to Valley Forge Road. Also, there are five raised concrete manholes and a storm drain that are part of the base storm sewer system that passes below the site.

Small stands of trees are present at the base of the hillside on the western side of the site. Drainage swales are present along the length of the eastern, western, and southern margins of the site. The drainage that is present along the western margin below the trees is not as well defined-swale as are the other two swales. Water accumulating against the base of the hillside is channeled to the south by the natural gradient; however, the swale has no channel south of the hill. The drainage swale along Forrestal Drive at the southern margin flows eastward and the swale parallel to Valley Forge Road Flows southward to discharge into a grated stormwater drain in the southeast corner of the site (Figure 4).

Information concerning the site's geology and soils, biology, meteorology, and other environmental setting information are contained in the following subsections.

3.1 Geology and Soils

Within the area comprising NAVSTA Roosevelt Roads, there are major variations in the topographic features. The regional area of the Naval Station consists of an interrupted narrow coastal plain with small valleys extending from the Sierra de Luquillo range, which has been deeply eroded by streams into valleys several hundreds of feet deep. Slopes of 30 to 45 degrees are common.

In the immediate area of the station, elevations range from sea level to approximately 295 feet. Immediately to the north of the station boundary, the hills rise abruptly to heights of 800 to 1,050 feet above sea level. There are a series of three hilly areas on the station, two of which separate the southern airfield area from the Port/Industrial, Housing, and Personnel Support areas. The third set of hills is called the Bundy area. Along the shoreline, lagoons and swamps are common.

The underlying geology of the station area is predominantly volcanic rock composed of lava and tuft, as well as sedimentary rocks derived from discontinuous beds of limestone. These rocks range in age from early Cretaceous to middle Eocene. The volcanic rocks and interbedded limestones have been complexly faulted, folded, metamorphosed, and intruded by dioritic rocks. This complex geological restructuring occurred sometime after the deposition of the limestone during the middle Tertiary age.

In addition to the predominate volcanic and sedimentary rock, the northwestern and western sectors of the base are covered by unconsolidated alluvial deposits deposited during the Quaternary period (Figure 5).

The primary geologic formations on and near NAVSTA Roosevelt Roads are various beach deposits, alluvium, quartz diorite and granodiorite, quartz kerotophyre, the Daguao Formation, an Figuera lava (see Appendix C).

There are six soil associations found on NAVSTA Roosevelt Roads, four of which are found primarily on the station, while the other two are limited to the western boundary of the station in the vicinity of the airfield. Two of the soil associations cover more than one-half of the station's surface area and are equally distributed. They are the Swamps-Marshes and Mak-Rio-Arriba-Cayagua Associations. The Swamps-Marshes Association is deep, poorly drained sandy or clayey, contains organic material from decaying mangrove trees, and is found slightly above sea level, on level or slightly level areas, and during high tide is covered or affected by salt or brackish water. Below the soil, there are deposits of coral, shells, and marl at varying depths. The Maki-Rio-Arriba-Cayagua Association is generally deep, poorly to moderately well-drained, clayey, or nearly level to moderately steep soils found on foot and side slopes, terraces, and alluvial fans.

The Descalabrada-Guayama and Caguabo-Mucara-Naranjito Associations cover most of the remaining surface area of the station. They are shallow to moderately deep, well drained, and are strongly sloping to steep soils on volcanic uplands. The Descalabrado-Guayama Association soils are found primarily in the hilly areas directly inland and adjacent to the Swamp-Marshes Association.

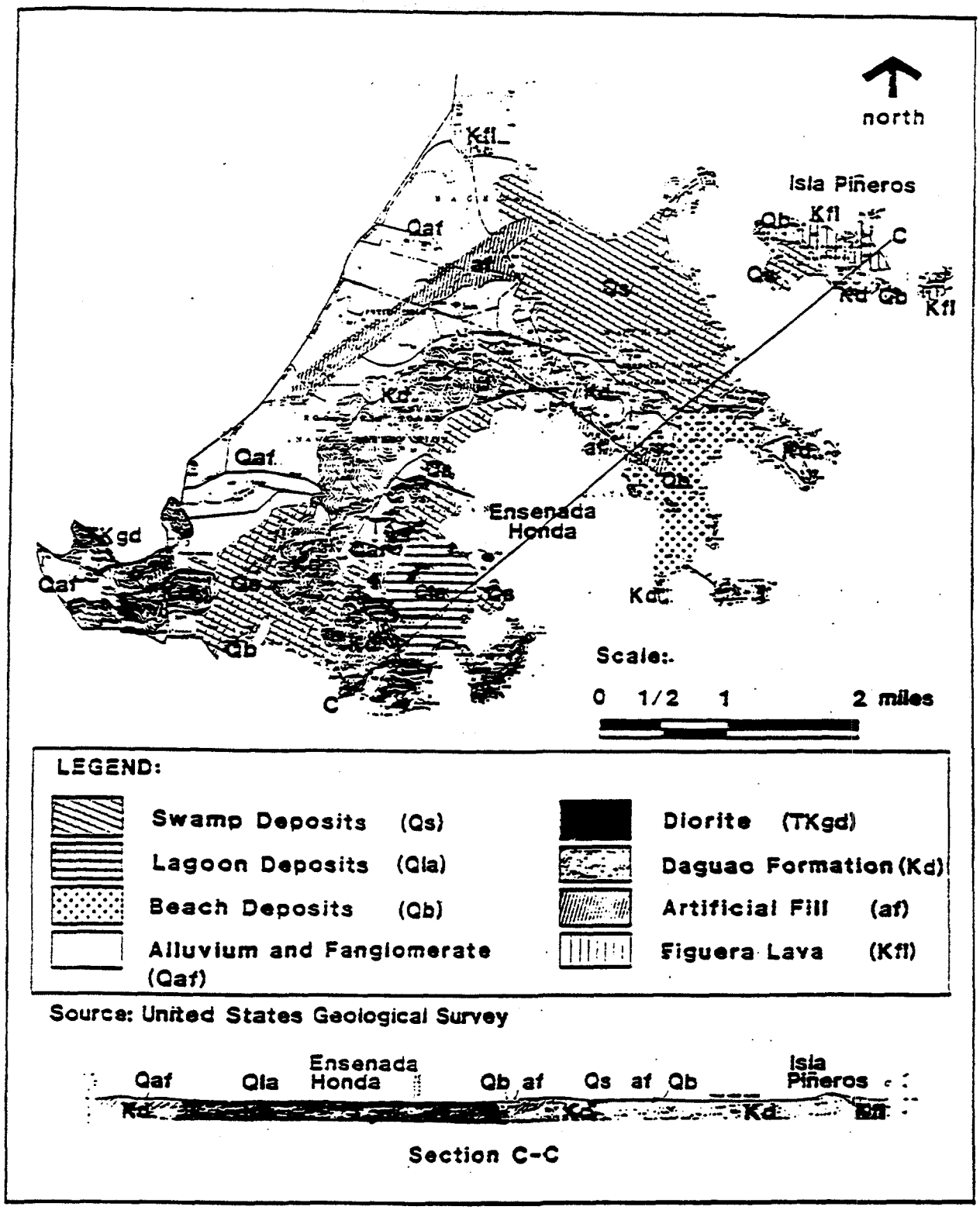

FIGURE 5
GEOLOGIC MAP OF NAVAL STATION
ROOSEVELT ROADS, PUERTO RICO

The remaining two soil associations are the Coloso-Toa-Bajura and Jacan-Amelia Fraternidad Associations. The Coloso-Toa-Bajura Association consists of deep, moderately well-drained to poorly drained, nearly level soils found in flood plains. While the Jacena-Amelia Fraternidd Association consists of moderately well-drained, nearly level to strong sloping soils on foot slopes, terraces and alluvial fans.

Substation 2 (Site 15) is located on the southern side of the base on the northeastern side of Enseneda Honda with shallow, well-drained soil underlaid by coral. The bedrock in this area is the Daguao Formation. This volcanic rock makes up the hill side on the northwestern side of the site. The Daguao Formation consists of interbedded volcanic breccia, lava, and occasionally volcanic sandstone. Between the volcanic bedrock and their soil layer are coral deposits of recent age. The thickness of the coral is not known; however, volcanic rock is also present at the surface in some areas of Site 15, suggesting that the coral is not thick in this area.

3.2 Ground Water

Water from alluvial aquifers along the coast of the Naval Station is of a calcium bicarbonate type, and has high concentrations of iron and manganese. The source of these minerals is unknown, but they may be derived from buried swamp or lagoon deposits.

A seawater-freshwater interface is present in the aquifers throughout the coastal areas of Puerto Rico, usually within a short distance inland of the coastline. Based on their proximity to the sea, ground water at Site 15 is probable saline. NAVSTA Roosevelt roads has no ground-water wells used for drinking water supplies.

Little information exists concerning the geohydrology of NAVSTA Roosevelt Roads in the immediate vicinity of Site 15. The only known possible sources of ground water are lenticular beds of clay, sand gravel, and rock fragments which occur at a depth of less than 30 meters. Monitoring wells have been installed at other IAS sites at NAVSTA Roosevelt Roads; however, none are properly located to provide information concerning Site 15. Some wells were developed further inland, upgradient of the station, in the nearby town of Ceiba, some 3 kilometers from base headquarters. However, they were abandoned due to high levels of salinity (Greenleaf/Telesca, 1984).

3.3 Surface and Subsurface Water

The surface waters that flow across the northeastern plain of Puerto Rico, where the Naval Station is located, originate on the eastern slopes of the Sierra de Luquillo mountains.

Surface runoff is channeled into various rivers and streams that eventually flow into the Caribbean Sea. In the low-lying shore areas, seawater flooding results from storms, wind, and abnormally high tides. The tidal ranges in the Roosevelt Roads area are rather small, with a maximum spring range of less than 3 feet.

Surface water drainage from Site 15 generally flows through the storm water sewers to the north or northwest into the mangrove swamps and into Ensenada Honda (Figures 2, 3, and 4).

3.4 Biology

The NAVSTA Roosevelt Roads has four distinct ecosystems. They are: the upland forest, mangrove, marine, and freshwater ecosystems. The upland forest area includes trees with compound or simple leaves that are succulent or leathery with broad expansive crowns. The trees rarely get higher than 45 feet, and function as an erosion inhibitor, are the habitat used primarily by avian species.

There are three recognized mangrove associations at Roosevelt Roads: the riverine, fringe, and basin. The mangrove ecosystems are perhaps the most important habitat type encompassed by the station. They provide cover, food, and nursery areas for the varied marine sport and commercial fish species, and marine organisms. They also provide nesting and roosting areas for a variety of birds. The marine ecosystems can be generally characterized as coral reef and seagrass associations. The coral reefs are made up of stony and soft coral. Many of the coral reefs are pristine in more remote areas of NAVSTA Roosevelt Roads. The seagrass beds consist of turtlegrass and manatee grass are common in the clean, shallow embayments of the station. Their extent in Ensenada Honda alone is approximately 600 acres. The vegetation allows sediments to settle out of the water, and serves as food and cover for the myriads of marine vertebrates and invertebrates.

The fresh water ecosystem at Roosevelt Roads consists of two small ponds near the airport and Officers' Club. The ponds tend to dry seasonally, due to lack of rain.

3.5 Climate

The climate is classified as tropical-maritime, with uniform temperatures ranging from 64°F to 88.2°F. The coolest months are January and February, with average temperature of 82.0°F. The warmest months are August and September with an average temperature of 88.2°F. The average annual precipitation at NAVSTA Roosevelt Roads is 60 inches and the rainy season extends from May through October.

The prevailing wind direction reflects the easterly trade winds. However, the differential heating of the land and sea during the day tends to give a more northerly component to the flow on the northern side of the island and a more southerly component on the southern side. During the night, a land breeze causes a prevailing southeasterly flow in the north and a prevailing northeasterly flow over the southern coast. The mean annual wind velocity is 5.5 knots, with a minimum in November and a maximum in August. Gales associated with westward moving disturbances in the trade winds or hurricanes passing either north or south of the area have the highest probability of occurrence from June through October.

The Hurricane season is from mid-June through mid-September; maximum winds exceed 95 knots during severe hurricanes. An average of two tropical storm per year occur in the area, one of which usually reaches hurricane intensity.

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4.0 NATURE AND EXTENT OF CONTAMINATION

Soil, sediment, wipe, chip samples have been collected in accordance with the work plans prepared for this site.

The remedial investigation at Site 15 emphasized the compilation and evaluation of existing data; collection of additional information to fill any gaps in the ESE (1988) data needed to characterize contamination on and off site; and the determination of the extent of contamination, migration pathways, and the potential receptors.

The primary goals of the RI are as follows:

- To define the nature and extent of PCB contamination from the pollution sources identified using previous (ESE, 1988) and newly collected data.
- To identify and evaluate contamination migration pathways and potential routes of exposure.
- To evaluate risks to potential receptors.
- To identify and define parameters affecting the feasibility of potential remedial alternatives.

Analytical results for each media (soil, sediment, concrete, and surficial wipes will be discussed separately. Contaminant concentration data from the samples collected during the May 1990 RI field activities are included in this section and compared with available ARARs wherever possible.

4.1 Soil Analytical Results

During the May 1990 RI field activities, soil samples were collected from 28 locations. These locations were based on a uniform grid at 30-foot centers (Figure 4). The areas covered by the grid were intended to supplement the existing data from the ECE (1988) investigation (Figures 3 and 6). ESE PCB data ranged from 0.58 mk/kg to 980 mg/kg. Versar data ranged from 0.16 mg/kg to 110 mg/kg for surficial data. It was only possible to collect deep (8" to 12") soil samples in four locations: S-1, S-13, S-19, and S-24. In Table 4-1, shallow soil (0" to 3") samples are designated with the letter, "A", as in S-1A; the designation, "D", following the sample location number indicates a duplicate.

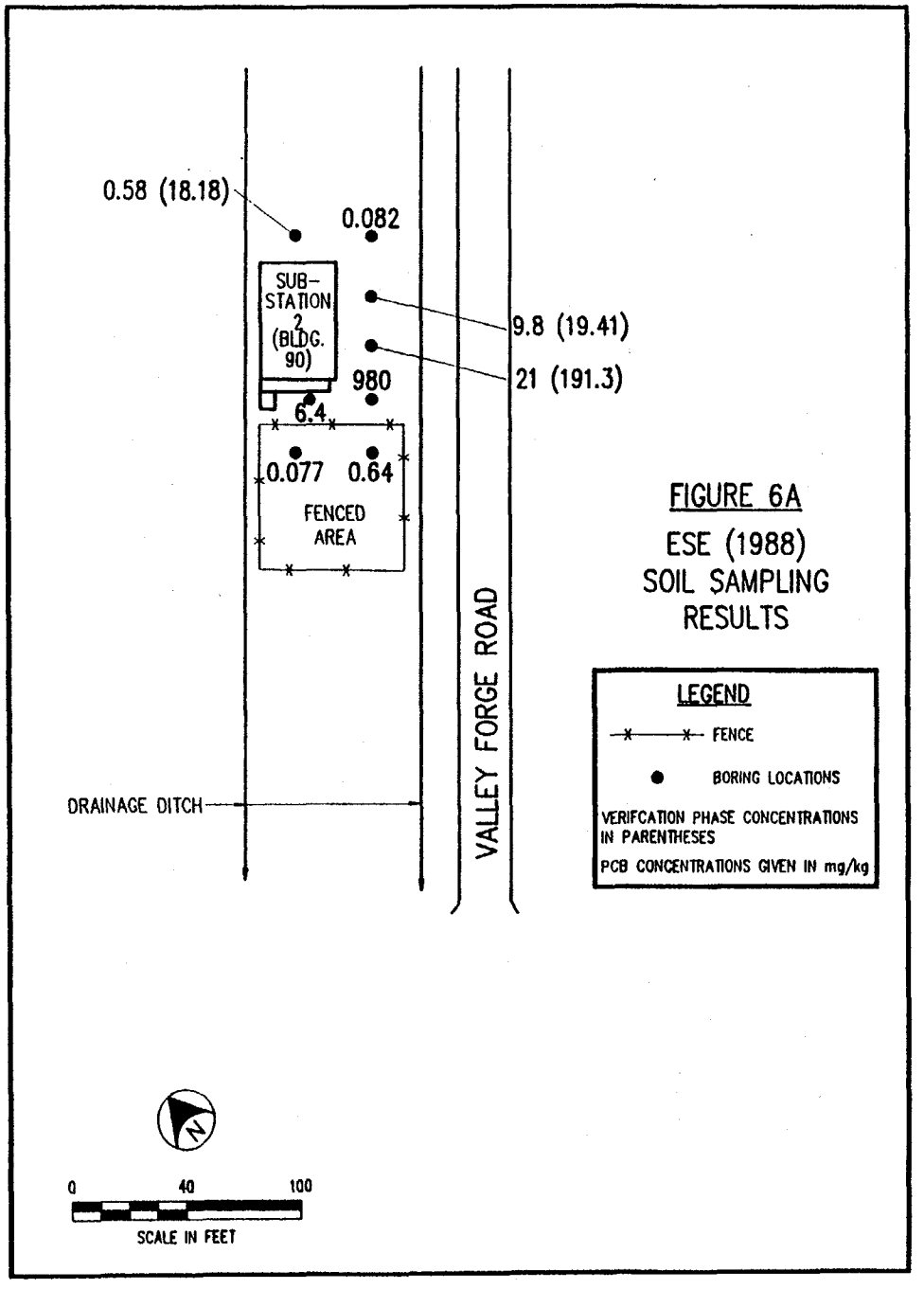

FIGURE 6A

ESE (1988) SOIL SAMPLING RESULTS

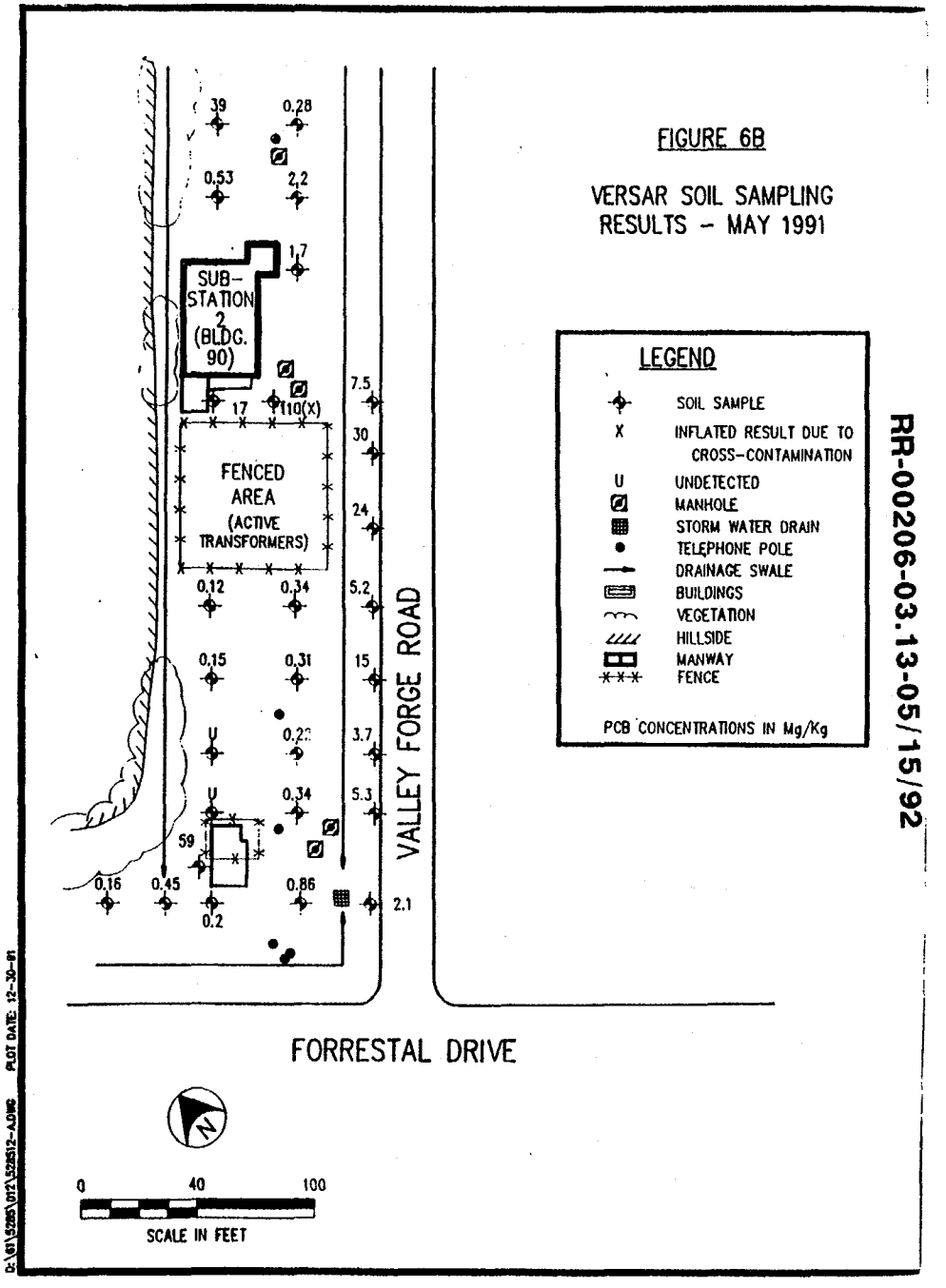

FIGURE 6B

VERSAR SOIL SAMPLING RESULTS - MAY 1991

RR-00206-03.13-05/15/92

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TABLE 4-1

Versar May 1991 Soil Sampling Results
Arochlor, PCB Concentration (mg/kg)

Sample No.	1016	1221	1232	1242	1248	1254	1260	Batch No.
RR15S01A	0.27 U	0.27 U	0.27 U	0.27 U	0.27 U	0.55 U	36	4795
RR15S01B	0.26 U	0.26 U	0.26 U	0.26 U	0.26 U	0.5 U	39	4795
RR15S02A	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.055 U	0.28	4795
RR15S03A	0.027 U	0.027 U	0.027 U	0.027 U	0.027 U	0.055 U	0.53	4795
RR15S04A	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.055 U	2.2	4795
RR15S05A	0.0215 U	0.0215 U	0.0215 U	0.0215 U	0.0215 U	0.055 U	0.25	4795
RR15S05AD	0.021 U	0.021 U	0.021 U	0.021 U	0.021 U	0.05 U	1.7	4795
RR15S06A	0.255 U	0.255 U	0.255 U	0.255 U	0.255 U	0.5 U	7.5	4795
RR15S95DA	0.0245 U	0.0245 U	0.0245 U	0.0245 U	0.0245 U	0.049 U	5.4	4795
RR15S07A	0.275 U	0.275 U	0.275 U	0.275 U	0.275 U	0.55 U	30	4795
RR15S08A	0.29 U	0.29 U	0.29 U	0.29 U	0.29 U	0.6 U	24	4795
RR15S09A	0.0215 U	0.0215 U	0.0215 U	0.0215 U	0.0215 U	0.055 U	0.12	4795
RR15S10A	0.021 U	0.021 U	0.021 U	0.021 U	0.021 U	0.05 U	0.34	4795
RR15S11A	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.5 U	5.2	4795
RR15S12A	0.0255 U	0.0255 U	0.0255 U	0.0255 U	0.0255 U	0.05 U	0.15	4795
RR15S13A	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.055 U	0.31	4795
RR15S13B	0.027 U	0.027 U	0.027 U	0.027 U	0.027 U	0.055 U	0.055 U	4795
RR15S14A	0.26 U	0.26 U	0.26 U	0.26 U	0.26 U	0.55 U	15	4795
RR15S15A	0.026 U	0.026 U	0.026 U	0.026 U	0.026 U	0.05 U	0.05 U	4795
RR15S16A	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.06 U	0.22	4795
RR15S17A	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.055 U	3.7	4795
RR15S18A	0.031 U	0.031 U	0.031 U	0.031 U	0.031 U	0.06 U	0.06 U	4795
RR15S19A	0.023 U	0.023 U	0.023 U	0.023 U	0.023 U	0.055 U	0.34	4795
RR15S19B	0.0235 U	0.0235 U	0.0235 U	0.0235 U	0.0235 U	0.055 U	0.055 U	4795
RR15S29A	0.255 U	0.255 U	0.255 U	0.255 U	0.255 U	0.5 U	5.3	4795
RR15S21A	0.265 U	0.265 U	0.265 U	0.265 U	0.265 U	0.55 U	110 X	4795
RR15S22A	0.26 U	0.26 U	0.26 U	0.26 U	0.26 U	0.5 U	17	4795
RR15S23A	0.026 U	0.026 U	0.026 U	0.026 U	0.026 U	0.05 U	2.1	4795
RR15S24A	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.055 U	0.86	4795
RR15S24B	0.027 U	0.027 U	0.027 U	0.027 U	0.027 U	0.054 U	0.52	4795
RR15S25A	0.0305 U	0.0305 U	0.0305 U	0.0305 U	0.0305 U	0.0605 U	0.29	4795

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TABLE 4-1 Versar May 1991 Soil Sampling Results Arochlor, PCB Concentration (mg/kg)								
Sample No.	1016	1221	1232	1242	1248	1254	1260	Batch No.
RR15S25AD	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.0555 U	0.2	4795
RR15S26A	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.056 U	1.5	4795
RR15S26A	0.285 U	2.85 U	0.285 U	0.285 U	0.285 U	0.55 U	59	4795
RR15S27A	0.0205 U	0.0205 U	0.0205 U	0.0205 U	0.0205 U	0.05 U	0.45	4795
RR15S28A	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.055 U	0.16	4795

Notes:

U = Undetected.
X = Inflated results due to cross contribution by PCBs in a mixture.

Data from duplicate soil samples indicate fair agreement in concentration values for duplicates at S-05A (0.25, 1.7 mg/kg) and S-25A (0.29, 0.20 mg/kg). There was a fairly large difference in the concentration data for S-26A (1.5, 59 mg/kg). Such a finding in a sandy soil, like that of Site 15, generally indicates that PCB contaminants are tightly bound to the soil, so that small quantities of a contaminated fraction of the aliquots will skew the data. This implies moderate degree of variability in the data obtained from samples from the site, and corresponding degree of uncertainty in the data base. ESE's (1988) previous data also indicate similar order of magnitude differences were evident in data from the same location between the verification and characterization sampling rounds.

Data from both sets are somewhat variable from one location to the next, and in the case of the ESE (1988) data, from one round of sampling to the next. Because the source of the PCB contamination results from slops and spills during the change-out of transformer fluids, such variability over short distances is to be expected. Areas where the transformers may have been emptied have higher concentrations, but other areas would also have sporadic detections resulting from drips and spills occurring as the transformers were moved from place to place, was tracked by workers, or distributed by the wheels of vehicles moving on the site.

As an industrial area with unrestricted access, the applicable ARARs is the 10 mg/kg TSCA standard. The 10 mg/kg standard was exceeded in seven of the 28 sample locations in the Versar data and four of the eight sample locations in the ESE (1988) data (Figure 6). Generally, the contaminated soil area is confined to the areas surrounding Substation No. 2 and transformer pad locations. The Versar data confirm the variability and the relative concentrations of the PCB data from areas near Substation No. 2 where confirmatory samples were collected: S-5, S-21, and S-22 (Figure 4 and 6).

4.2 Sediment Samples Results

Sediment samples were collected from seven locations during the May 1990 RI field activities to extend the data set, upgradient and downgradient of ESE's (1988) data base (Figure 7). One sample location, SD-7, was selected to coincide with the ESE (1988) data (Figure 3 and 7). ESE PCB concentrations detected in sediments ranged from 0.45 to 1,186 mg/kg. Versar data measured PCB concentrations between not detected at 0.055 mg/kg to 22 mg/kg (Table 2). It was possible to collect deeper samples (8" to 12") in four of the sediment locations: SD-1, SD-3, SD-4, and SD-7. In Table 4-2, the surficial sediment sample is designated with the letter "A" as in SD-1A; the letter, "B" indicates a deeper (8" to 12") sample; and letter, "D", denotes a duplicate sample.

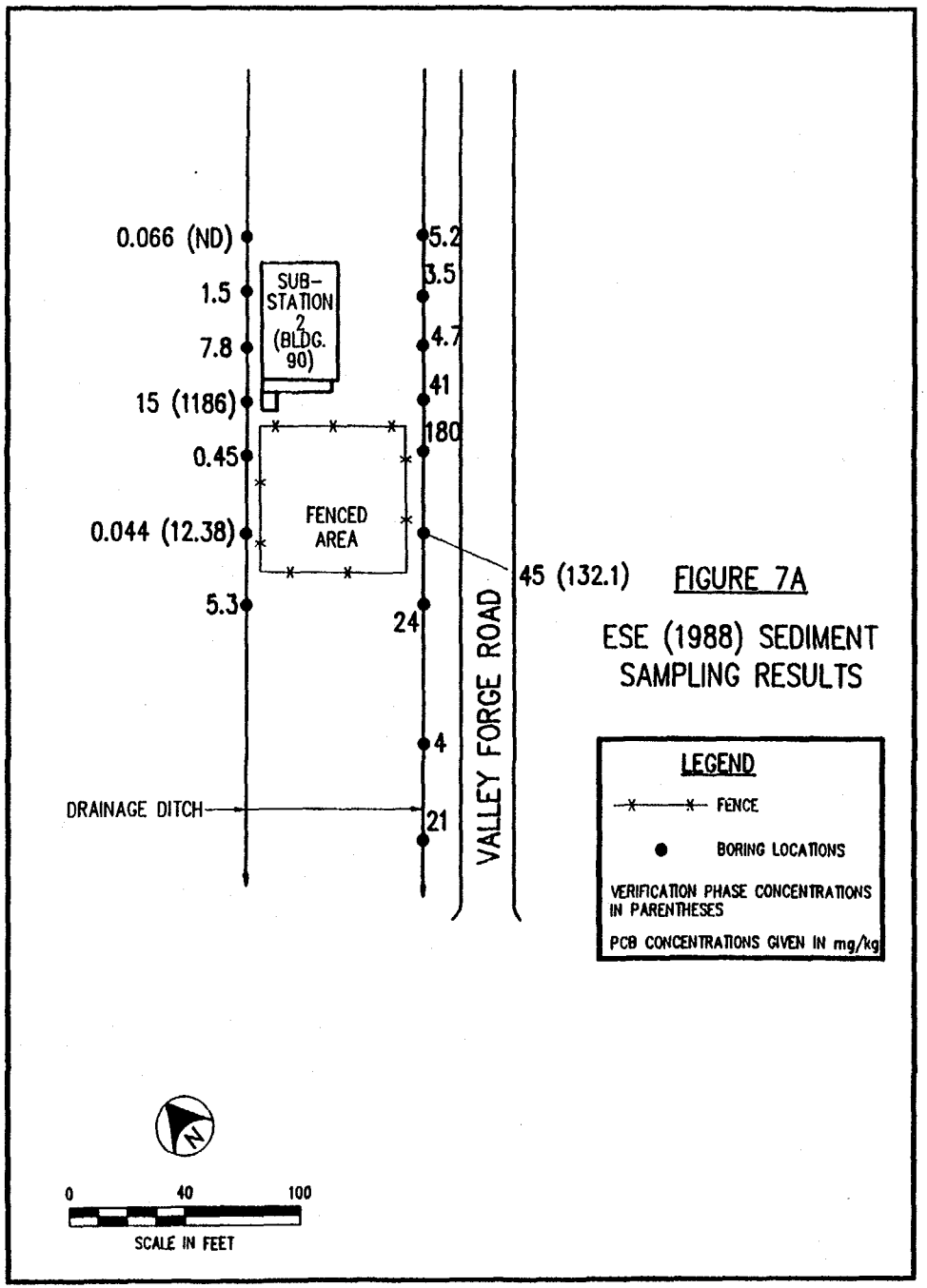

FIGURE 7A

ESE (1988) SEDIMENT SAMPLING RESULTS

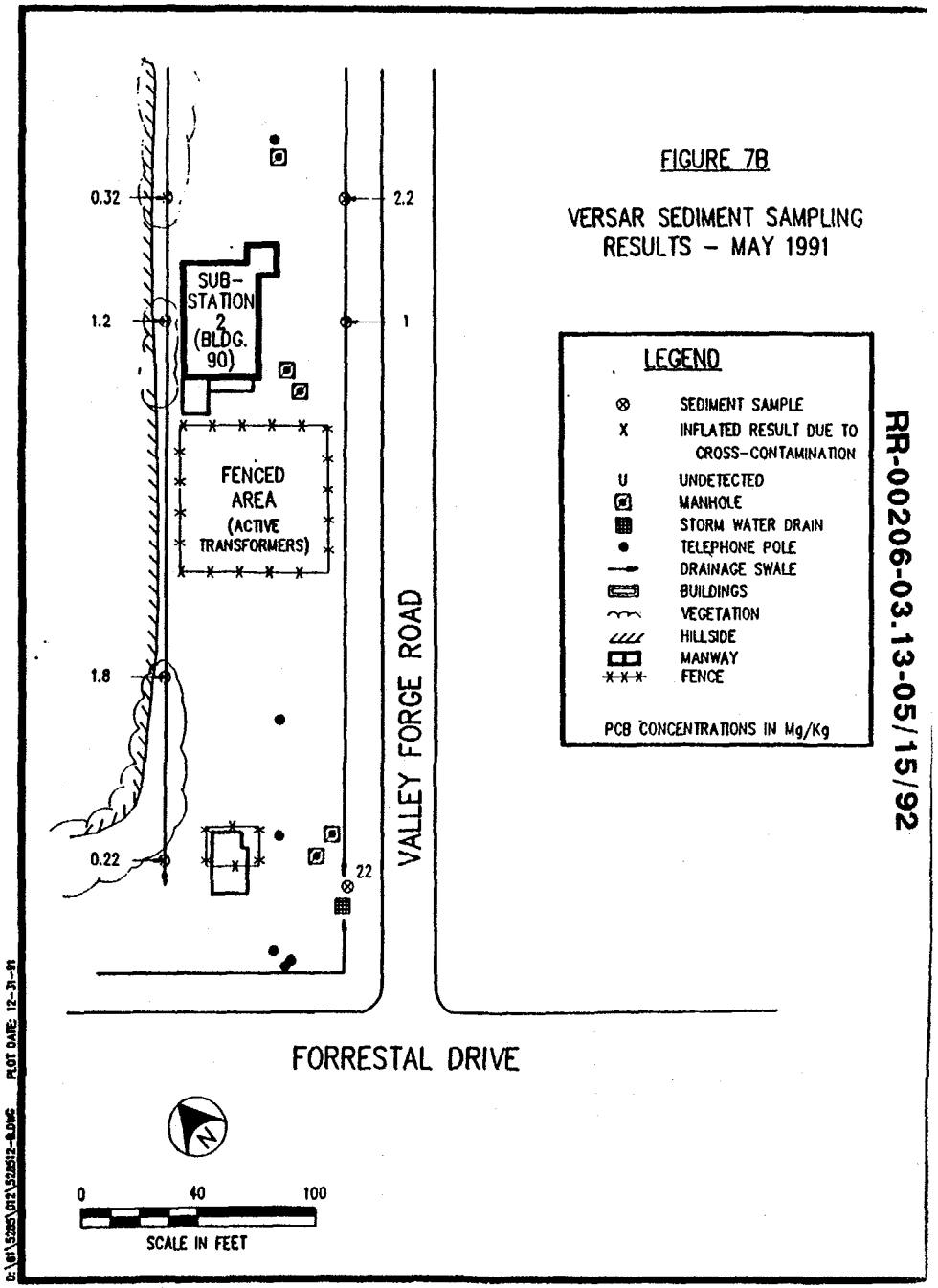

FIGURE 7B

VERSAR SEDIMENT SAMPLING RESULTS - MAY 1991

RR-00206-03.13-05/15/92

Versar INC

TABLE 4-2

Versar May 1991 Sediment Sampling Results
Arochlor, PCB Concentration (mg/kg)

Sample No.	1016	1221	1232	1242	1248	1254	1260	Batch No.
RR15SDO1A	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.06 U	0.32	4795
RR15SD01B	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.055 U	0.055 U	4795
RR15SD02A	0.0325 U	0.0325 U	0.0325 U	0.0325 U	0.0325 U	0.065 U	1.2	4795
RR15SD03A	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.055 U	1.8	4795
RR15SD03B	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.0295 U	0.06 U	0.87	4795
RR15SD04A	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.0275 U	0.055 U	0.22	4795
RR15SD04B	0.0265 U	0.0265 U	0.0265 U	0.0265 U	0.0265 U	0.055 U	0.17	4795
RR15SD05A	0.038 U	0.038 U	0.038 U	0.038 U	0.038 U	0.075 U	2.2	4795
RR15SD06A	0.029 U	0.029 U	0.029 U	0.029 U	0.029 U	0.06 U	1	4795
RR15SD06AD	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.0285 U	0.055 U	0.97	4795
RR15SD07A	0.36 U	0.36 U	0.36 U	0.36 U	0.36 U	0.7 U	15	4795
RR15SD07B	0.295 U	0.295 U	0.295 U	0.295 U	0.295 U	0.6 U	22	4795

Notes:

U = Undetected.

Data from the duplicate sediment sample, SD-6A and SD-6AD indicate very good agreement of 1.0 and 0.97 mg/kg, respectively. Data from the shallow (0 to 3") and deep (8" to 12") soil sample also demonstrate good agreement, although the deeper sample is generally very slightly lower in concentration. The only exception is SD-7A and SD-7B where the PCB concentrations are 15 and 22 mg/kg, respectively. The average of these two locations, 18.5 mg/kg, compares favorably with 21 mg/kg PCBs measured by ESE (1988) for this location. The ESE (1988) data indicate a moderate to high variability in the PCB concentrations observed at the same location during two different rounds. Such variability is not altogether unexpected, because the sediment has similar sandy properties as the soil at the site.

ARARs for PCBs in sediment are the interim sediment quality criteria (EPA, 1990) of 19 mg/kg for fresh water and 33 mg/kg for salt water. The ESE (1988) sediment data greatly exceed the ARAR in the immediate vicinity of Substation No. 2 (Figure 7) in the general vicinity of the area where extensive soil contamination was also noted (Figure 6). The data from location SD-7 (Table 4-2, Figure 7) indicate that the sediment adjacent to the storm drain is below freshwater and saltwater ARARs.

Because the drainage swales are often dry and the sediment is essentially identical to the surrounding soil on either side of the swale, the TSCA 10 mg/kg soil ARAR is a relevant standard. A reasonable application of this standard would require the removal of all of the material between the hillside, and the substation and large transformer area. The sediment and soil bounding the site and Valley Forge Road, south of Substation No. 2 would also require treatment.

4.3 Wipe and Chip Sample Results

Three wipe samples and two chip samples were collected during RI field activities in May 1990. There are no concrete surfaces present at the site except for manhole covers and a small porch-like structure at the entrance to Building 90. Only the porch area had visible stains. ESE (1988) did not attempt to characterize these or other stained concrete. Data from wipe samples ranged from not detected at 1.0 $\mu g/m^2$ to 121 $\mu g/m^2$ (Table 4-3, Figure 8), all well below the 1,000 $\mu g/m^2$ ARAR (10 $\mu g/100\ cm^2$) set for outdoor high contact surfaces under TSCA for industrial areas and nonrestricted access areas.

Data from the two concrete chips collected in this area detected PCB concentrations at 1.6 to 7.2 mg/kg. Both detections are below the 10 mg/kg ARAR. These are fair agreement in the trends for PCB concentration between wipes and chips from the same locations. The

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TABLE 4-3 Versar May 1991 Wipe and Chip Sample Results Arochlor, PCB Concentration (µg/m²)								
Wipe Sample No.	1016	1221	1232	1242	1248	1254	1260	Batch No.
RR15W01	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1 U	6.5	4774
RR15W02	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U	4774
RR15W03	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	80 X	121 X	4774
Arochlor, PCB Concentration (µg/m²)								
Chip Sample No.	1016	1221	1232	1242	1248	1254	1260	Batch No.
RR15C02	0.245 U	0.245 U	0.245 U	0.245 U	0.245 U	0.49 U	7.2	4774
RR15C01	0.025 U	0.025 U	0.025 U	0.025 U	0.025 U	0.05 U	1.6	4774

Notes:

U = Undetected.
X = Inflated results due to cross contribution by PCBs in a mixture.

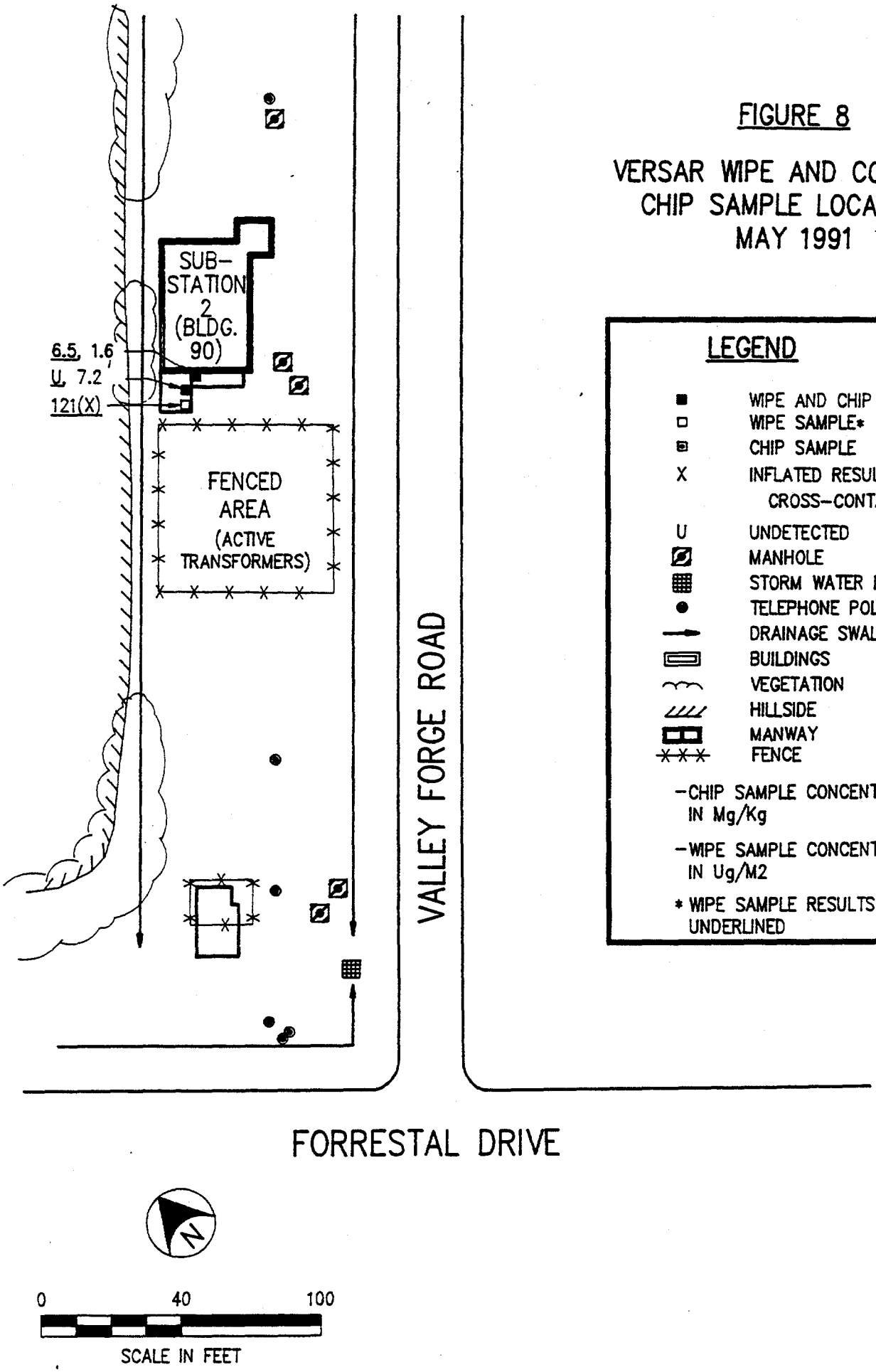

FIGURE 8

VERSAR WIPE AND CONCRETE CHIP SAMPLE LOCATIONS MAY 1991

LEGEND

- WIPE AND CHIP SAMPLE*
- WIPE SAMPLE*
- CHIP SAMPLE
- X INFLATED RESULT DUE TO CROSS-CONTAMINATION
- U UNDETECTED
- MANHOLE
- STORM WATER DRAIN
- TELEPHONE POLE
- DRAINAGE SWALE
- BUILDINGS
- VEGETATION
- HILLSIDE
- MANWAY
- FENCE

-CHIP SAMPLE CONCENTRATIONS IN Mg/Kg

-WIPE SAMPLE CONCENTRATIONS IN Ug/M2

* WIPE SAMPLE RESULTS ARE UNDERLINED

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highest concentration from a wipe sample corresponds with the highest concentration chip sample.

The wipe sample data from wipe sample RR15W03 suggest that remediation of the concrete surfaces at Site 15 may be necessary. Due to the warm weather conditions that rapidly dried the gauze pad used for sampling and the very rough nature of the deeply weathered concrete surfaces, it is likely that the wipe sample data may under represent the concentration of PCBs contained in the stained concrete surfaces.

4.4 Site Characterization Summary

Using the Versar May 1991 data and the data from ESE (1988), areas requiring remediation under the 10 mg/kg TSCA ARAR can be delineated (Figure 9). The outlines of this region is bounded by physical barriers (such as the hillside or roadways) or by sample data showing concentrations of PCBs less than 10 mg/kg at all locations, except RR15S01 where 39 mg/kg were detected.

Confirmatory samples will be required during remedial action to determine whether the coral below the site is extensively contaminated (after the overlying soil has been stripped off). At this time, additional shallow soil samples northeast of RR15S01 will be required to confirm that all soil exceeding the ARAR has been removed.

Although data from RR15S01 indicate that some additional soil may need to be removed in the northernmost part of the site, it is unlikely that the amount of additional remediation will require large volumes of soil to be removed, based on the available data on the amount of contaminants spilled, and soil and sediment data from this investigation. Additional remediation requirements are believed to be defined in sufficient detail to be within the +50 to -30 percent accuracy range for the cost estimates within the FS.

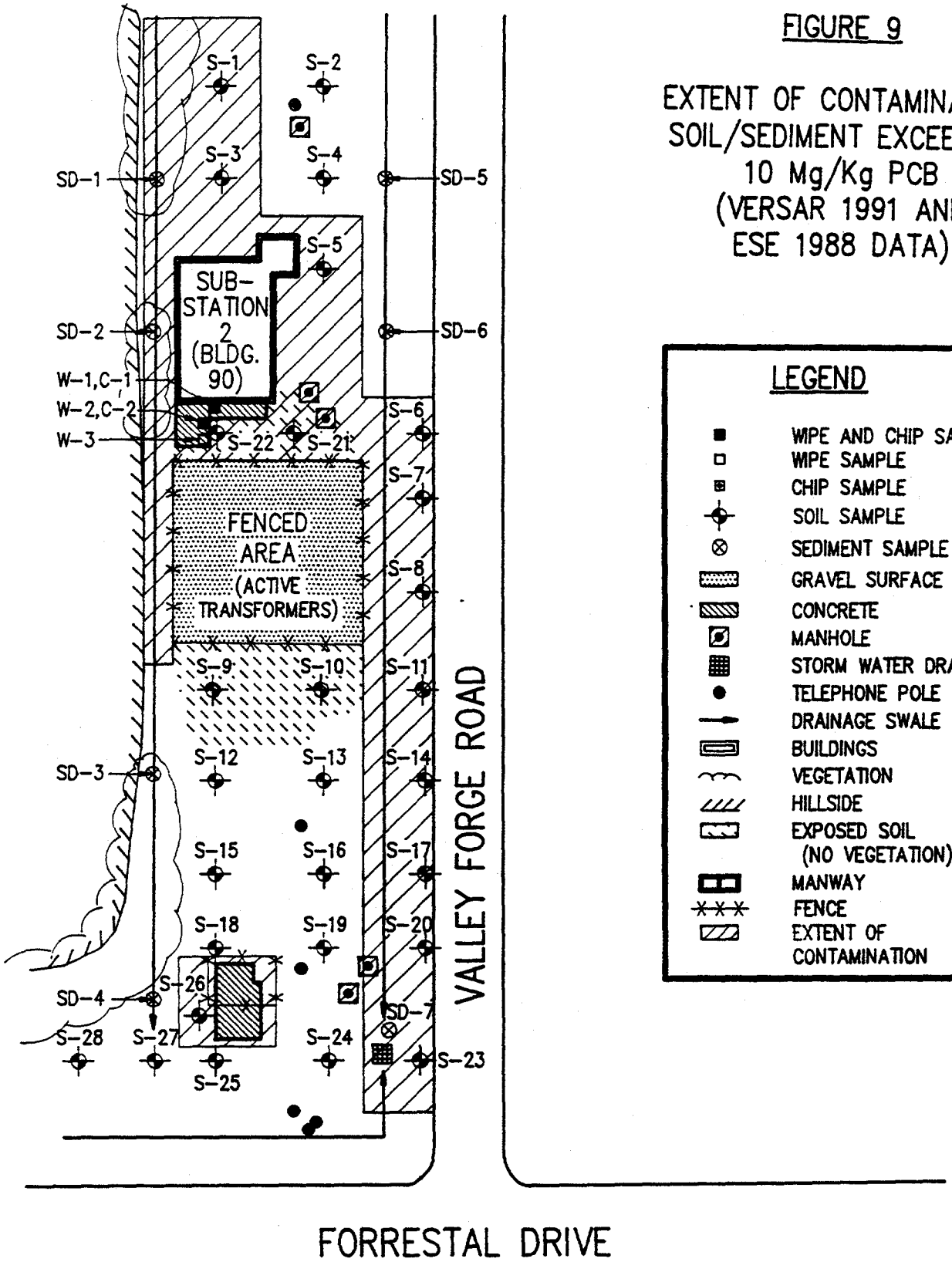

FIGURE 9

EXTENT OF CONTAMINATION SOIL/SEDIMENT EXCEEDING 10 Mg/Kg PCB (VERSAR 1991 AND ESE 1988 DATA)

LEGEND

- WIPE AND CHIP SAMPLE
- WIPE SAMPLE
- CHIP SAMPLE
- SOIL SAMPLE
- SEDIMENT SAMPLE
- GRAVEL SURFACE
- CONCRETE
- MANHOLE
- STORM WATER DRAIN
- TELEPHONE POLE
- DRAINAGE SWALE
- BUILDINGS
- VEGETATION
- HILLSIDE
- EXPOSED SOIL (NO VEGETATION)
- MANWAY
- FENCE
- EXTENT OF CONTAMINATION

D:\5295\004\FIG23A-X.DWG

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5.0 BASELINE RISK ASSESSMENT

The risk assessment for Site 15 focuses on known site contaminants identified through the field activities conducted as part of the RI and previous investigations (ESE, 1989). The principal contaminants of concern identified during these investigations were PCBs. Arachlor 1260 was found in all samples where PCBs were detected; Arachlor 1254 was found in only one soil sample. Arochlor 1248 was also found in only one soil sample; and Arochlor 1242 was found in only one sediment sample. The Arachlor 1254 sample result was flagged to indicate that the result may be inflated due to analytical interference resulting from a PCB mixture. The Arochlor 1242 sample result was flagged to indicate that the sample suggests the presence of PCB in the quantitation analysis but was not confirmed in the secondary analysis.

Analytical data collected by Versar are presented in Tables 4-1, 4-2, and 4-3. The data validation reports are contained in Appendix A. Validated data were used to calculate a mean concentration and a 95 percent upper confidence limit (UCL) around the mean. The 95 percent UCL concentration indicates that 95 percent of the PCB concentrations at Site 15 will be below this value. This value is used to yield a conservative estimate of risk. It was assumed that PCBs, if not detected in a sample, were present in a sample at one-half the detection limit. This prevents biasing the mean either high or low. Table 5-1 presents the 95 percent UCL concentrations for each media on Site 15.

5.1 Fate and Transport

PCBs are a family of compounds that vary widely in physical, chemical and biological properties. For compounds with fewer than five chlorine atoms per molecule, biodegradation by soil microorganisms appears to be the dominant fate process, resulting in significant destruction and transformation. PCBs with 5 or more chlorine atom per molecule can be photolyzed with ultraviolet light. This process can be extremely slow; however, it may the most important degradation process for PCBs.

Nondestructive processes that affect the distribution and transport of PCBs are absorption, volatilization and bioaccumulation. In natural water systems, PCBs may be sorbed to the suspended and bed sediments due to their very low solubility in water. PCBs' tendency for absorption increases with the degree of chlorination and organic content of the sorbent. Once bound, the PCBs may persist for years with slow desorption providing continuous, low-level exposure to the surrounding locality. PCB-compounds may also be strongly partitioned and accumulated into biota. When bioaccumulation does occur, most of the absorbed PCBs are stored in the adipose (i.e., fatty) tissue.

TABLE 5-1
95% UCL for Each Media at Site 15
Naval Station Roosevelt Roads

COMPOUND	SOIL 95% UCL (mg/Kg)	SEDIMENT 95% UCL (mg/Kg)
Arachlor 1242	NA	NA
Arachlor 1248	NA	NA
Arachlor 1254	NA	NA
Arachlor 1260	1.21E+01	7.18E+00

PCBs are relatively inert and, therefore, persistent in the environment. PCBs have low vapor pressures and high log octonol/water partition coefficients. Despite their low vapor pressures, PCBs have a high water activity coefficient and a higher rate of volatilization than might be expected. Volatilization and transport as an aerosol followed by fallout of dust or precipitation is the probable cause of the ubiquitous distribution of PCBs in the environment. At Site 15, PCBs are localized near Building 90 and the transformer pads due to the nature of site use (i.e., draining and maintenance of transformers). It is very likely that PCB oils leaked onto the ground in the areas where the transformer fluids were changed, and from drips and spills as the transformers were moved from one location to another. The more highly chlorinated species are less volatile than the lighter species. The presence of suspended solids tends to reduce volatilization because the solids absorb PCBs and reduce PCB concentration in solution.

Individual PCBs vary widely in their physical properties according to the degree and position of chlorination. Because PCBs have very low solubilities in water, and a high dielectric constant, they were used widely in industrial processes. Additionally, PCBs have excellent thermal stability and are strongly resistant to oxidation and hydrolysis.

5.2 Exposure Assessment

The objective of this exposure assessment is to estimate the type and magnitude of exposures to the contaminants of concerns on or migrating from the site. This section evaluates exposures for their possibility and plausibility, and quantitatively estimates exposures. For the purposes of this risk assessment, any potential exposures from contaminants inside site buildings will not be included in this risk assessment; the interiors of the buildings are being considered separately, as another operable unit.

An exposure is considered to be complete if all four of the following elements are intact:

(1) a contaminant source and release mechanism
(2) a contaminant migration pathway
(3) an exposure point and mechanism for uptake
(4) a receptor

This section will address these elements with respect to Site 15. The results of this exposure assessment were combined with toxicity information to characterize potential risks.

5.2.1 Identification of Potential Exposure Pathways

This section develops the potential exposure pathways associated with the site. Migration pathways will be identified and evaluated. Exposure point concentrations, chemical intakes and resulting risks can then be estimated.

Several migration pathways are possible for contaminant releases at Site 15. These include air, soil, and sediment. There are no persistent surface-water bodies present on site.

5.2.1.1. Air Pathways

There are two pathways for contaminant releases into the air: volatilization and fugitive dust emissions. The sampling locations were screened using a photoionization detector (PID), but no elevated readings were noted. Analyses for volatile compounds were not conducted, and air samples were not collected. Additionally, the site's proximity to the ocean provides for relatively continuously breezy conditions, greatly minimizing the potential for hazardous atmospheres given the soil concentrations observed on site. Therefore, this pathway will not be evaluated.

The second air pathway, the release of fugitive dust particles may be of concern at the site. The soils at the site are characterized as coarse to medium sand. Additionally, the central portion of the site is unvegetated (Figure 4). The remainder of the site is covered with grasses or other vegetation. The bare portion of the site is potentially amenable to high wind erosion potential; however, as of the writing of this manual, there are no toxicity constants accepted by EPA for the inhalation of PCBs. Therefore, this pathway cannot be evaluated at this time.

5.2.1.2 Soil Pathways

Contaminants present in soil may contribute to air contamination via fugitive dust emissions, ground water via infiltration, and surface water via soil erosion and runoff. However, these contributions will probably be insignificant compared to the risks from direct contact with soils through inadvertent ingestion and dermal absorption.

Inadvertent soil ingestion is usually evaluated in the context of children between 1 and 6 years of age. However, soil ingestion is typically possible for site workers (adult), trespassers (child and adult), and future residents (adult and child) on the site. Although the site is currently part of a naval station, EPA guidance requires that the site be evaluated for risks from residential use either by the Navy, or by a future landowner. Additionally, although

portions of the site are fenced and access is limited to workers at the naval station, the site, for the most part, is not fenced off. Residents and children residing at the naval station could potentially gain access to the site. Exposures would occur by sitting or standing in the sand. These activities will be evaluated for risk to children because they represent the more sensitive population. These scenarios are limited to exposures to surface soils.

Exposures to subsurface soils would be plausible for excavation workers at the site; however, excavation work at the site is expected to be of short duration (i.e., 2 weeks). Exposures of less than 3 months are difficult to assess. Additionally, subsurface soils are not present at most sampling locations providing a limited data base of samples for statistical evaluation. Coral occurs at a depth of approximately 1 foot over most of the site.

5.2.1.3 Sediment Pathways

There are soil residues and sediments present in the drainage ditches and swales at Site 15. These ditches are open and readily accessible to trespassing children from the naval station. Exposure to contaminants in the sediments could occur via incidental ingestion and dermal absorption. These pathways will be evaluated in the risk assessment. Workers on the site are not expected to have prolonged unprotected contact with the sediments. Also, it can be assumed that the ditches will be filled and replaced with subsurface drains if residences are constructed in the future.

5.2.1.4 Surface Water Pathways

Surface water bodies are not present on the site. There are drainage ditches (drainage swales) that periodically collect stormwater; however, these drain quickly and it is unlikely that children would wade there during rainstorms. Furthermore, given the low solubility of PCBs, there is little potential for contaminants leaching from soil or sediment during the brief periods where water flows through these ditches. Therefore, the exposure scenarios associated with surface water pathways will not be evaluated for Site 15.

5.2.1.5 Ground-water Pathways

As discussed in previous sections of this report, any ground-water contamination will be considered as a separate operable unit, and not evaluated as part of this risk assessment. Although PCBs in soil may migrate slowly into the ground water, site ground water is reportedly saline, and is therefore nonpotable (Greenleaf/Telesca, 1984). Therefore, no exposure would take place under current or future scenarios.

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5.2.2 Potentially Significant Exposure Pathways

Based on the discussion above, the following exposure pathways are considered potentially significant and will be evaluated:

1. Direct ingestion of surface soils by trespassing and future on-site residential children

2. Dermal absorption of surface soils by trespassing and future on-site residential children

3. Direct ingestion of surface soils by workers at Site 15

4. Dermal absorption of surface soils by workers on Site 15

5. Direct ingestion of soil/sediments in drainage ditches by trespassing children on Site 15

6. Dermal absorption of soil/sediments in drainage ditches by trespassing children on Site 15

The selection of these exposure pathways is presented in Figure 10.

5.2.3 Evaluation of Exposure and Chemical Intakes

This chapter includes detailed descriptions and related calculations that estimate exposure point concentrations for each identified exposure pathway.

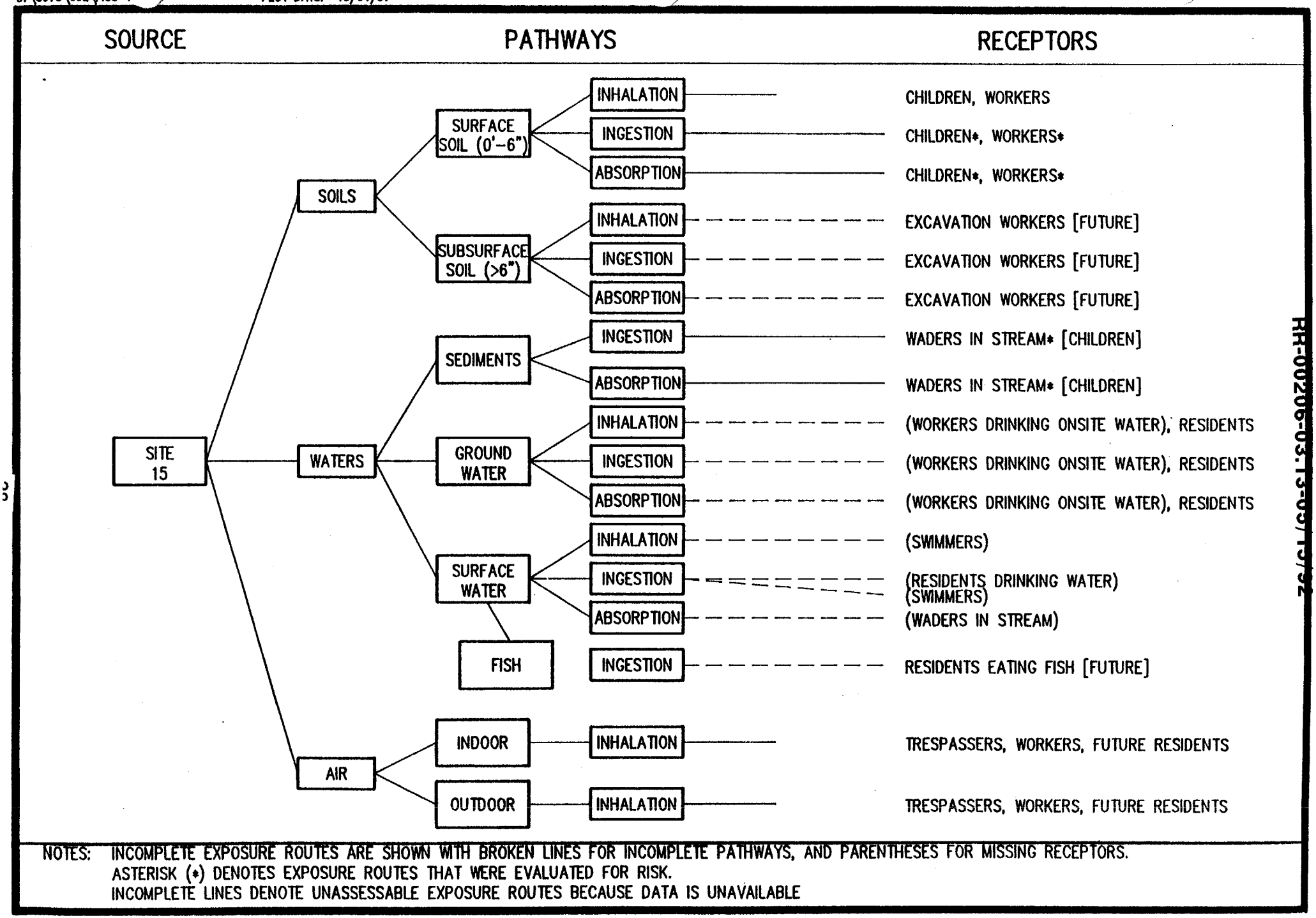
The chemical intakes for potential receptors were estimated using the formulas recommended in EPA's Risk Assessment Guidance for Superfund (U.S.EPA, 1989). For each exposure route, intakes were calculated in units of milligrams of chemical per kilogram of body weight on a daily basis. The general equation for this calculation is

$$I = \frac{C \times CR \times EF \times ED}{BW \times AT}$$

where:

I = intake (mg/kg-day),
C = chemical contraction at exposure point (mg/kg),
CR = contact rate (g/event),

D:\5975\002\FIG3-1 PLOT DATE: 10/04/91



NOTES: INCOMPLETE EXPOSURE ROUTES ARE SHOWN WITH BROKEN LINES FOR INCOMPLETE PATHWAYS, AND PARENTHESES FOR MISSING RECEPTORS.
ASTERISK (*) DENOTES EXPOSURE ROUTES THAT WERE EVALUATED FOR RISK.
INCOMPLETE LINES DENOTE UNASSESSABLE EXPOSURE ROUTES BECAUSE DATA IS UNAVAILABLE

FIGURE 10
EXPOSURE ROUTES AT SITE 15, NAVSTA, ROOSEVELT ROADS

RR-00206-03.13-03/13/92

EF = exposure frequency (events/year),
ED = exposure duration (hours),
BW = body weight of exposed individual (kg), and
AT = period of time over which exposure is averaged (days).

Additional route-specific terms may be introduced into the equation to account for other important factors such as rates of absorption, percent of chemical absorbed in the body and site soil characteristics.

The values for some of the variables in the intake equations must be assumed. Most of these assumptions are standardized and recommended values are published by EPA in various guidance documents. Other variables are site-related and situation-specific, and must be estimated using best professional judgment. In all cases, conservative values were used to provide an overestimation of risk, thus, ensuring protection of public health.

5.2.3.1 Surface Soil Ingestion Exposure

The surface soil ingestion scenario was evaluated to consider possible inadvertent ingestion of contaminants in the surface soil by trespassing or future residential children, and by site workers.

<u>Children</u>

Because of the temperate climate for the region, it is feasible that children will be playing on the site year-round either as on-site trespassers from the Naval Station or as future residents.

The equation for estimating intakes via inadvertent soil ingestion is:

$$\text{Intake} = \frac{C_s \times IR \times CF \times EF \times ED}{BW \times AT}$$

where:

C_s = contaminant concentration in soil (mg/kg),
IR = ingestion rate (mg soil/day),
CF = conversion factor (kg soil/mg soil),
EF = exposure frequency (days/year),
ED = exposure duration (years),
BW = body weight (kg), and
AT = averaging time (days).

Values assigned to these variables for children are:

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C_s = 95% UCL from Table 5-1
IR = 200 (U.S.EPA, 1991a)
CF = 10^{-6}
EF = 350 (U.S.EPA, 1991a)
ED = 6 (U.S.EPA, 1991a)
BW = 15 (U.S.EPA, 1991a)
AT = 2,190 (U.S. EPA, 1991a)

Table 5-2 shows the input variables and calculations of intakes for trespassing children and children of future on-site residents.

Adult Workers

The soil ingestion equation used for adults would be identical to that used for workers; however, the values assigned to the variables would differ. The values used for the adult worker soil ingestion scenario are as follows:

C_s = 95% UCL from Table 5-1
IR = 100 (U.S.EPA, 1991a)
CF = 10^{-6}
EF = 250 (U.S.EPA, 1991a)
ED = 25 (U.S.EPA, 1991a)
BW = 70 (U.S.EPA, 1991a)
AT = 25,690 (U.S. EPA, 1991a)

Table 5-2 presents dose calculations for adult workers inadvertently ingesting soil.

5.2.3.2 Surface Soil Dermal Absorption

Children

Dermal exposure to children would expect to take place at the same frequency as incidental ingestion; therefore all the variables corresponding to exposure duration and frequency are identical. There are a few route-specific variables used in the equation. Skin surface area available for exposure would be hands, arms, and legs. This would total 0.391 m^2, or 3,910 cm^2.

Exposure will also be affected by the soil-to-skin adherence, which is dependent on the amount of clay in the soil. Site soils contain little clay and are made up almost exclusively of sand. Typical adherence factors used are 1.45 mg/cm^2 for commercial potting soil and 2.77 mg/cm^2 for pure kaolin clay. For the purposes of this risk assessment, the soil-to skin adherence value for commercial potting soil (1.45 mg/cm^2) was used as a conservative estimate of soil adherence.

TABLE 5-2
Incidental Ingestion of Soil (Site Workers)
Naval Station Roosevelt Roads

COMPOUND	Soil Concentration (mg/kg)	Ingestion Rate (mg/day)	Conversion Factor (kg/mg)	Exposure Frequency (days/year)	Exposure Duration (years)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg-day)	Carcinogenic CDI (mg/kg-day)
Arachlor 1242	NA	100	1E-06	250	25	70	9125	25550	NA	NA
Arachlor 1248	NA	100	1E-06	250	25	70	9125	25550	NA	NA
Arachlor 1254	NA	100	1E-06	250	25	70	9125	25550	NA	NA
Arachlor 1260	1.21E+01	100	1E-06	250	25	70	9125	25550	1.19E-05	4.24E-06

Incidental Ingestion of Soil (Children)

COMPOUND	Sediment Concentration (mg/kg)	Ingestion Rate (mg/day)	Conversion Factor (kg/mg)	Exposure Frequency (events/year	Exposure Duration (years)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg/day)	Carcinogenic CDI (mg/kg/day)
Arachlor 1242	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1248	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1254	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1260	1.21E+01	200	1E-06	350	6	15	2190	25550	1.55E-04	1.33E-05

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Once soil particles have adhered to the skin, it is unlikely that all of the contaminants will be sorbed from the soil through the skin-cell membranes into the bloodstream. Information on soil absorption through the skin is limited and the intake calculated would be an absorbed dose, not an ingested dose. However, cancer slope factors available in the literature are usually based on ingestion of contaminants, which do not account for absorption through the skin. Therefore, 100 percent absorption from the soil through the skin will be assumed. This also ensures that a conservative estimate of risk will be calculated. The equation for estimating dose via soil absorption is:

$$\text{Intake} = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

C_s = contaminant concentration in soil (mg/kg)
CF = conversion factor (kg soil/mg soil)
SA = skin surface area available for contact (cm^2/event)
AF = soil to skin adherence factor (mg soil/cm^2)
ABS = absorption factor (unitless)
EF = exposure frequency (events/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

Values assigned to these variables for children are:

C_s = 95 percent UCL from Table 1
CF = 10^{-6}
SA = 3,910 (U.S. EPA, 1989)
AF = 1.45 (U.S. EPA, 1989)
ABS = 100
EF = 350 (U.S.EPA, 1991a)
ED = 6 (U.S.EPA, 1991a)
BW = 15 (U.S.EPA, 1991a)
AT = 2,190 (U.S. EPA, 1991a)

Table 5-3 shows the input variables and calculations of intakes for trespassing children and children of future on-site residents.

Adult Workers

The same equation is used for children and adults to calculate exposures to soils via dermal absorption; however, assumptions for body weight and exposure times must be adjusted. It can be assumed that site workers will be wearing long pants, eliminating the leg

TABLE 5-3
Dermal Contact with Soil (Site Workers)
Naval Station Roosevelt Roads

COMPOUND	Soil Concentration (mg/kg)	Conversion Factor (kg/mg)	Skin Surface Area (cm2/event)	Adherance Factor (mg/cm2)	Exposure Frequency (events/year)	Exposure Duration (years)	Absorption Factor (unitless)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg-day)	Carcinogenic CDI (mg/kg-day)
Arachlor 1242	NA	1E-06	3120	1.45	250	25	1	70	9125	25550	NA	NA
Arachlor 1248	NA	1E-06	3120	1.45	250	25	1	70	9125	25550	NA	NA
Arachlor 1254	NA	1E-06	3120	1.45	250	25	1	70	9125	25550	NA	NA
Arachlor 1260	1.21E+01	1E-06	3120	1.45	250	25	1	70	9125	25550	5.37E-04	1.92E-04

Dermal Contact with Soil (Children)

COMPOUND	Soil Concentration (mg/kg)	Conversion Factor (kg/mg)	Skin Surface Area (cm2/event)	Adherance Factor (mg/cm2)	Exposure Frequency (events/year)	Exposure Duration (years)	Absorption Factor (unitless)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg/day)	Carcinogenic CDI (mg/kg/day)
Arachlor 1242	NA	1E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1248	NA	1E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1254	NA	1E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1260	1.21E+01	1E-06	3910	1.45	350	6	1	15	2190	25550	4.39E-03	3.77E-04

surface area from exposure. The total surface area available for exposure would be from the hands and arms, a total of 0.312 m^2, or 3,120 cm^2. The values assigned to the equation variables for an adult worker are:

C_s = 95% UCL from Table 5-1
CF = 10^{-6}
SA = 3,120 (U.S. EPA, 1989)
AF = 1.45 (U.S. EPA, 1989)
ABS = 100%
EF = 250 (U.S.EPA, 1991a)
ED = 25 (U.S.EPA, 1991a)
BW = 70 (U.S.EPA, 1991a), and
AT = 25,690 (U.S. EPA, 1991a).

Table 5-3 shows the input variables and calculations of intakes for trespassing children and children of future on-site residents.

5.2.3.3 Sediment Ingestion

The sediment ingestion scenario was evaluated to consider possible inadvertent ingestion of contaminants in the sediments by trespassing children.

Because of the temperate climate for the region, it is feasible that children from the Naval Station could play on the site year-round.

The equation for estimating intakes via inadvertent sediment ingestion is:

$$\text{Intake} = \frac{C_s \times IR \times CF \times EF \times ED}{BW \times AT}$$

where:

C_s = contaminant concentration in sediment (mg/kg)
IR = ingestion rate (mg soil/day)
CF = conversion factor (kg sediment/mg sediment)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

Values assigned to these variables for children are:

C_s = 95% UCL from Table 5-1
IR = 200 (U.S.EPA, 1991a)
CF = 10-6

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EF = 350 (U.S.EPA, 1991a)
ED = 6 (U.S.EPA, 1991a)
BW = 15 (U.S.EPA, 1991a)
AT = 2,190 (U.S. EPA, 1991a)

Table 5-4 shows the input variables and calculations of intakes for trespassing children via the sediment ingestion scenario.

5.2.3.4 Sediment Dermal Absorption

The same assumptions used for the dermal absorption of soils can be used for the sediments. Sediments from Site 15 are derived from the site soils.

Values assigned to the dermal absorption equation variables for children are:

C_s = 95% UCL from Table 5-1
CF = 10^{-6}
SA = 3,910 (U.S. EPA, 1989)
AF = 1.45 (U.S. EPA, 1989)
ABS = 100%
EF = 350 (U.S.EPA, 1991a)
ED = 6 (U.S.EPA, 1991a)
BW = 15 (U.S.EPA, 1991a)
AT = 2,190 (U.S. EPA, 1991a)

Table 5-5 shows the input variables and calculations of intakes for trespassing children from dermal absorption of sediments.

5.3 Toxicity Assessment

The objective of this toxicity assessment is to provide a summary of the potential health and environmental hazards that may be associated with PCBs at Site 15 at NAVSTA Roosevelt Roads through the exposure routes identified in the previous section of this report. Available information concerning human health effects and environmental toxicity were included for PCBs. Arachlor-specific information was also included where applicable.

It is not the intent of this section to provide a comprehensive summary of all toxicological information; rather, it provides a summary of available information at the time as it relates to the exposure scenarios evaluated in this report. The complete IRIS listing for PCBs is given in Appendix D.

TABLE 5-4
Incidental Ingestion of Stream Sediments (Children)
Naval Station Roosevelt Roads

COMPOUND	Sediment Concentration (mg/kg)	Ingestion Rate (mg/day)	Conversion Factor (kg/mg)	Exposure Frequency (days/year)	Exposure Duration (years)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg/day)	Carcinogenic CDI (mg/kg/day)
Arachlor 1242	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1248	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1254	NA	200	1E-06	350	6	15	2190	25550	NA	NA
Arachlor 1260	7.18E+00	200	1E-06	350	6	15	2190	25550	9.18E-05	7.87E-06

TABLE 5-5
Dermal Contact with Stream Sediment While Recreating (Children)
Naval Station Roosevelt Roads

COMPOUND	Sediment Concentration (mg/kg)	Conversion Factor (kg/mg)	Skin Surface Area (cm2/event)	Adherence Factor (mg/cm2)	Exposure Frequency (events/year)	Exposure Duration (years)	Absorption Factor (unitless)	Body Weight (kg)	Non-Carc Averaging Time (days)	Carcinogenic Averaging Time (days)	Non-Carc CDI (mg/kg-day)	Carcinogenic CDI (mg/kg-day)
Arachlor 1242	NA	1.00E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1248	NA	1.00E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1254	NA	1.00E-06	3910	1.45	350	6	1	15	2190	25550	NA	NA
Arachlor 1260	7.18E+00	1.00E-06	3910	1.45	350	6	1	15	2190	25550	2.60E-03	2.23E-04

5.3.1 Chemical Characteristics

Polychlorinated biphenyls (PCBs) constitute a large class of compounds produced by the partial (or complete) chlorination of the biphenyl molecule (U.S. EPA, 1976). Commercial PCBs are mixtures of isomers of chlorinated biphenyls exhibiting varying degrees of chlorination.

5.3.2 Noncancer Toxicity

PCBs have a low acute toxicity, but because of their high absorption rate, high lipid solubility, low water solubility, and relative chemical inertness, PCBs tend to concentrate in the food chain, accumulate in body fat, persist in biological tissue, and show persistent toxicity (U.S. EPA, 1976).

The major routes of entry of PCBs into the human body are inhalation, ingestion, and absorption. Studies have shown that all routes have approximately the same affects on the body. The majority of these studies have been on animals, predominantly mice and rats, as well as guinea pigs and monkeys. The classical pathological changes in the liver of animals exposed to PCBs include infiltration of fat, increased cell and liver size, degeneration of cellular contents, and ultimately cell death. The latent nature of these effects is demonstrated by the fact that most severe histopathology known occurred 5 to 13 weeks after PCB ingestion has ceased. PCBs have also been shown to enhance the effects of other carcinogens in mice and rats.

In humans exposed to PCBs in the work place or through accidental contamination of food, reported adverse effects include chloracne (a long-lasting disfiguring skin disease), impairment of liver function, a variety of neurobehavioral and affective symptoms, menstrual disorders, and minor birth abnormalities. There is inadequate, yet suggestive, evidence of excess liver cancer in humans by ingestion, inhalation, or dermal contact.

5.3.2.1 Animal Studies

Animal studies have demonstrated that the potencies of the individual compounds vary according to the degree and position of chlorination. A study of rhesus monkeys was performed in 1974 and included the feeding of 25 ppm of Aroclor 1248 for 2 months. The average total intake of PCBs was approximately 250 mg. The effects on all the monkeys included facial swelling, liver necrosis and reproductive inability. Additionally, reproductive and neurobiological effects were reported at the lowest dose level tested, 11 µg/kg body weight/day over a period of several months. The surviving monkeys continued to have high

adipose tissue levels, acne, tissue swelling and hair loss 2 years after this short term, low level exposure (U.S. EPA, 1972).

Dermal toxicity studies have been performed on rabbits using technical PCB samples which contained an average of 60 percent chlorine. Studies have shown lesions of the skin, liver, and kidneys in the rabbits. Studies have also shown possible immunosuppressive effects in rabbits (U.S. EPA, 1972).

PCBs have been shown to affect reproduction in several different species. Egg production, egg hatchability, and shell thickness were decreased by feeding low levels of various PCB mixtures to chickens (U.S. EPA, 1972). Female rats fed 20 ppm of Aroclor 1254 had a decrease in the number of litters and litter size. In a two-generation study, 5 ppm was the no effect level for rat reproduction. Higher dietary levels caused decreased rat offspring survival and decreased mating performance. Even at 1 ppm, male rats were born with enlarged livers. In another study, levels as low as 2.5 ppm resulted in a marked decrease in the ability of monkeys to conceive.

A more recent study of occurred in 1981 at the State Office Building in Binghamton, New York. Electrical arcing and explosions caused the leakage of PCBs from an electrical transformer. Between 180 and 200 gallons of fluid containing Aroclor 1254 leaked from the transformer and was burned in the resulting fire. Toxicological studies using the soot from the Binghamton State Office Building showed that chick embryo teratogenicity and fetal lethality tests were positive. Liver ultrastructural changes were seen at all dose levels in one oral dose study in guinea pigs. These studies of the soot produced a LD50 value of 410 mg/kg. Dermal applications of the saline-moistened soot were administered to rabbits. Dermal inflammatory reactions were noted. The dermal minimum lethal dose in rabbits is from 1.26 to 2.00 g/kg (NIOSH, 1986).

PCBs are bioaccumulated and can be biomagnified; therefore, their toxicity increases with the length of exposure and place of the exposed species in the food chain. The toxicity of the various PCB mixtures is also dependent on their composition. There is some evidence that mixtures containing more highly chlorinated biphenyls are more potent inducers of hepatocellular carcinoma in rats than mixtures containing less chlorine by weight (IRIS, 1991b).

Three primary ways that PCBs can affect terrestrial wildlife are by inducing outright mortality, adversely affecting reproduction, and by changing behavior. PCBs generally can cause mortality in all species depending on the length and level of exposure. Some mammalian species are especially sensitive to PCBs. PCBs have caused lower egg

production, eggshell thinning, increased deformities, decreased hatchability, decreased growth and an increase in mortality in birds (Clement, 1985).

5.3.2.2 Human Episodes

A few cases of human exposure to PCBs have been noted. In 1968 in Yusho, Japan, a PCB containing 48 percent chlorine, had leaked into rice oil and was subsequently consumed by approximately 1,000 persons. The exposure levels calculated were approximately 15,000 mg/day. The average total dose causing an effect in these victims were reported at 2000 mg. The lowest level that produced human effect was reported at 500 mg (U.S. EPA, 1976).

The affects of the exposure included chloracne, pigmentation of skin and nails, weight loss, and fetal toxicity. Symptoms such as transient visual disturbance, feeling of weakness, numbness of limbs, and headache, are signs of damage to the nervous system.

In 1969 and 1970, 159 patients were examined. It was found that 50 percent still showed no clinical improvement. This shows an indication of persistence of PCBs in the human body (U.S. EPA, 1976).

Initial findings for the Binghamton State Office Building PCB fire recorded PCB air levels 80 µg/m3, in soot found in stairwells of 10 percent by weight, in soot found on the floor of 2,000 to 4,700 µg/m3. A voluntary medical surveillance of 50 of the 500 people believed to be exposed, showed chloracne, transient skin rashes, skin cancers, liver pathology, nervousness, irritability, difficulty sleeping, and fatigue (Schecter and Tiernan, 1985).

PCBs have been shown in studies to affect the human body by impairment of liver function, a variety of neurobehavioral symptoms, and affective symptoms. PCBs are bioaccumulated and can be biomagnified. Therefore, their toxicity increases with length of exposure. Toxicity of the PCBs mixtures also depends on their composition. There is some evidence that the mixtures containing more highly chlorinated biphenyls are more potent inducers of hepatocellular carcinoma in rats than mixtures containing less chlorine by weight.

5.3.3 Carcinogenicity

Evidence suggests that polychlorinated biphenyl mixtures containing more highly chlorinated biphenyls are more potent inducers of hepatocellular carcinoma in rats than mixtures containing less chlorine by weight. This may prove that the toxicity of PCB mixtures may be dependant on their composition.

Adenofibrosis has been reported in some studies. Abnormal growth and development of the gastric mucosa has also been reported, further evidence of the carcinogenic potential of PCBs.

The Health Effects Assessments Summary (HEAS) list PCBs in the carcinogenicity table (EPA, 1990). Table B of HEAS states that PCBs are a potential carcinogen by means of inhalation and oral exposures. Oral exposure has shown that rats being fed a diet of Aroclor 1254 for 6 and 11 months have demonstrated adenofibrosis. In a second study, female Sherman Strain rats were fed 100 ppm of Aroclor 1260 for approximately 21 months. This study concluded that Aroclor 1260 had a hepatocarcinogenic effect in these rats (U.S. EPA, 1976).

The EPA has assigned a drinking water unit risk value for PCBs of 2.2E-4 µg/L and a value for human exposure of 4.3396 $(mg/kg\text{-}day)^{-1}$. The slope factor for PCBs is 7.7 $(mg/kg\text{-}day)^{-1}$ (EPA 1991b). The case for the carcinogenic association of PCB exposure with human inhalation still needs conclusive evidence. The EPA classifies PCBs in Group B2, a probable human carcinogen. This classification indicates there is sufficient evidence of carcinogenicity in animals, but inadequate evidence of carcinogenicity in humans.

5.4 Risk Characterization

The objective of this risk assessment is to combine information on exposures and toxicity to evaluate potential human health risks associated with NAVSTA Roosevelt Roads Site 15. This section begins with a discussion and presentation of risk calculations for noncarcinogenic and carcinogenic effects of PCBs. These risks will be summed for each receptor group. The two receptor groups identified in this risk assessment are trespassing children and site workers. The site risks associated with each receptor population will be discussed in the following section.

5.4.1 Noncarcinogenic Contaminants

Noncarcinogenic impacts of chemicals on human health are evaluated by comparing projected or estimated intakes to reference levels for chemicals of concern. A reference level represents an exposure level at which there should be no observable adverse affects associated with a chemical. Reference doses (RfD) are the currently accepted human reference levels for noncarcinogenic effects. RfDs can be obtained from many sources. An RfD for PCBs was not available through IRIS or the Health Effects Summary Tables (EPA, 1990). Because PCBs have been identified as the principal contaminant of concern at Site 15, it is important that both carcinogenic and noncarcinogenic effects are assessed. The RfD

value used in this risk assessment was obtained from a study of adverse affects of PCB-contaminated fish, and is currently under consideration by EPA for inclusion in the IRIS data base.

As of this writing, there is no RfD developed for inhalation exposures. Exposures via ingestion and absorption were considered to be chronic (i.e., small doses over a long time period) rather than subchronic (i.e., large doses over a short period of time). Emphasis on subchronic risks has waned since U.S. EPA first introduced guidance for quantifying subchronic risks in 1986. Consequently, many subchronic RfDs have been repealed, and valid subchronic RfDs are only available for a few chemicals. Furthermore, the nature of the site and the work done make it more likely for chronic exposures to occur. Therefore, risks for subchronic exposures were not evaluated. Table 5-6 summarizes the toxicity values used in this risk assessment.

To determine if there is an unacceptable noncarcinogenic risk posed by Site 15, the calculated chronic daily doses (CDI) were compared to the RfD in the following manner:

$$\text{Hazard Index} = \frac{CDI_{PCB}}{RfD_{PCB}}$$

If the quotient exceeds one, there is unacceptable noncarcinogenic risk posed by Site 15 and there is a potential for adverse health effects on human health.

Tables 5-7 and 5-8 present the noncarcinogenic risk calculations for each of the receptor groups evaluated in each media.

5.4.1.1 Children

Dermal contact scenarios for both soils and sediments were above the target index of 1, indicating that there is the potential for adverse health effects from dermal exposure to PCBs on Site 15. This is a conservative estimate of risk and actual risks may actually be lower.

5.4.1.2 Site Workers

The soil hazard index from the dermal absorption pathway was slightly above the threshold value of 1. Consequently, adverse health effects may be experienced as a result of dermal absorption from soil. This is a conservative estimate of noncarcinogenic risk and

TABLE 5-6
Toxicity Values for PCB Arachlor Mixtures
Naval Station Roosevelt Roads

COMPOUND	INHALATION RfC	INHALATION SF	ORAL RfD	ORAL SF
Arachlor 1242	NA	NA	1.00E-04 *	7.70E+00
Arachlor 1248	NA	NA	1.00E-04 *	7.70E+00
Arachlor 1254	NA	NA	1.00E-04 *	7.70E+00
Arachlor 1260	NA	NA	1.00E-04 *	7.70E+00

* Value obtained from Dourson and Clark, 1990.

TABLE 5-7
Soil Hazard Indices (Adults)
Naval Station Roosevelt Roads

COMPOUND	Dermal Contact CDI (mg/kg-day)	Oral RfD (mg/kg-day)	Hazard Index (Intake/RfD)	Soil Ingestion CDI (mg/kg-day)	Oral RfD (mg/kg-day)	Hazard Index (Intake/RfD)
Arachlor 1242	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1248	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1254	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1260	5.37E-04	1.00E-04	5.37E+00	1.19E-05	1.00E-04	1.19E-01
	Absorption Hazard Index =		5.37E+00	Ingestion Hazard Index =		1.19E-01

Soil Hazard Indices (Children)

COMPOUND	Dermal Contact CDI (mg/kg/day)	Oral RfD (mg/kg/day)	Hazard Index (Intake/RfD)	Soil Inhalation CDI (mg/kg/day)	Oral RfD (mg/kg/day)	Hazard Index (Intake/RfD)
Arachlor 1242	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1248	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1254	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1260	4.39E-03	1.00E-04	4.39E+01	1.55E-04	1.00E-04	1.55E+00
	Absorption Hazard Index =		4.39E+01	Ingestion Hazard Index =		1.55E+00

TABLE 5-8
Sediment Hazard Indices (Children)
Naval Station Roosevelt Roads

COMPOUND	Sediment Incidental Ingestion CDI (mg/kg-day)	Oral RfD (mg/kg-day)	Hazard Index (Intake/RfD)	Sediment Dermal Contact CDI (mg/kg-day)	Oral RfD (mg/kg-day)	Hazard Index (Intake/RfD)
Arachlor 1242	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1248	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1254	NA	1.00E-04	NA	NA	1.00E-04	NA
Arachlor 1260	9.18E-05	1.00E-04	9.18E-01	2.60E-03	1.00E-04	2.69E+01

actual risk may be several orders of magnitude lower.

5.4.2 Carcinogenic Risk

Carcinogenic risk values are generally expressed in scientific notation. An individual lifetime risk of 1 in 10,000 is represented as 1.0E-04. Lifetime daily doses (LADEs) are multiplied by the carcinogenic potency factor (CPF) for that chemical. Carcinogenic risk is determined by the following equation:

$$\text{Risk} = LADE_{PCB} \times CPF_{PCB}$$

The impact of carcinogenic contaminants is assessed by comparing calculated risk to the acceptable range. The acceptable range of risks is 1.0E-04 to 1.0E-07, with a target level of 1.0E-06.

Tables 5-9 and 5-10 present the carcinogenic risk calculations for each receptor group in each media.

5.4.2.1 Children

The carcinogenic risks for all scenarios for children were above the target range of 1E-04 to 1E-06. Carcinogenic risks ranged from 1.02E-04 (soil ingestion) to 3.38E-02 (dermal absorption). Soil/sediment dermal absorption accounted for the highest risks. Once again, these risks are conservative estimates and actual risk may be several orders of magnitude lower.

5.4.2.2 Site Workers

The dermal contact scenario yielded a risk that was outside the target risk range of 1.0E-04 to 1.0E-06. Carcinogenic risks evaluated for adult workers were 1.48E-03 (dermal contact) and 3.26E-05 (soil ingestion). Actual risks may be lower.

5.4.3 Uncertainties

There are a number of uncertainties associated with risk estimates. These uncertainties are introduced because of (1) the need to extrapolate below the dose range of experimental tests using animals, (2) the variability of the receptor population, (3) assumed equivalency of dose-response relationships between animals and humans, (4) differences in experimental exposure routes (i.e., gavage) versus exposure routes expected on site and, (5) sampling

TABLE 5-9
Carcinogenic Risk Estimates for Soil (Adults)
Naval Station Roosevelt Roads

COMPOUND	Dermal Contact CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*SF)	Soil Ingestion CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*SF)
Arachlor 1242	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1248	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1254	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1260	1.92E-04	7.70E+00	1.48E-03	4.24E-06	7.70E+00	3.26E-05
	Absorption Carcinogenic Risk =		1.48E-03	Ingestion Carcinogenic Risk =		3.26E-05

Carcinogenic Risk Estimates for Soil (Children)

COMPOUND	Dermal Contact CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*CPF)	Soil Ingestion CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*RfD)
Arachlor 1242	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1248	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1254	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1260	4.39E-03	7.70E+00	3.38E-02	1.33E-05	7.70E+00	1.02E-04
	Absorption Carcinogenic Risk =		3.38E-02	Ingestion Carcinogenic Risk =		1.02E-04

TABLE 5-10
Carcinogenic Risk Estimates from Sediments (Children)
Naval Station Roosevelt Roads

COMPOUND	Sediment Incidental Ingestion CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*SF)	Sediment Dermal Contact CDI (mg/kg-day)	SF 1/(mg/kg-day)	Chemical-specific Risk (Intake*SF)
Arachlor 1242	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1248	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1254	NA	7.70E+00	NA	NA	7.70E+00	NA
Arachlor 1260	9.18E-05	7.70E+00	7.07E-04	2.23E-04	7.70E+00	1.72E-03
	Incidental Ingestion Carc. Risk =		7.07E-04	Absorption Carc. Risk =		1.72E-03

error in the environmental sampling data used to make the calculations. In addition to chemical concentration, route and duration of exposure, there are many other factors which may influence the likelihood of developing adverse health effects. These include differences between individual nutritional health and status, age, sex, inherited characteristics, and recreational habits (e.g., smoking vs. non-smoking) that may affect susceptibility.

5.5 Environmental Assessment

NAVSTA Roosevelt Roads is located on the east coast of Puerto Rico, bounded by private and public lands, the Caribbean Sea and offshore islands and keys. The total area of the station is 8,055 acres, approximately 70 percent available for fish and wildlife management. Station acreage is defined as follows:

30% improved: includes areas actively utilized for housing, administration, air operations, surface operations and other ancillary facilities;

12% semi-improved: includes small arms ranges, unpaved access roads, and improved areas that have been abandoned;

58% unimproved.

There are four ecosystems present on the base: tidal forests predominated by mangroves, coral reef associations, drywood coastal forests found in high relief areas in semi-improved or unimproved associations, and grassbeds present on improved and maintained semi-improved areas. Over 10 percent of Puerto Rico's mangrove forests are found on NAVSTA Roosevelt Roads.

The station also contains various marine ecosystems, generally characterized as coral reef associations and seagrass associations. The coral reefs are made of both stony and soft corals and utilized by a tremendous variety of marine fish.

Approximately 600 acres of seagrass beds, consisting of turtlegrass and manatee grass are common in the clear shallow embankments off the naval stations. These plants serve as food and cover for marine vertebrates and invertebrates.

The wide variety of habitat and temperate climate support a large number of species. Table 5-11 lists the fish species found on NAVSTA Roosevelt Roads. Table 5-12 presents a detailed species list of the avifauna found at the naval station as developed by the U.S. Fish and Wildlife Service (FWS 1978).

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TABLE 5-11 Fish in the Mangrove of Naval Station Roosevelt Roads	
Stringrays (Dasyatidae)	
Dasyatis americana	Southern Stingray
Aetobatis narinari	Spotted Eagle Bay
Tarpons (Elopidae)	
Megalops atlanticus	Tarpon
Herrings (Clupeidae)	
Opistahonema oglium	Thread Herring
Herengula humeralis	Red Ear Sardine
Lizardfishes (Synodontidae)	
Synodus interdedius	Sand Diver
Needlefishes (Belonidae)	
Stongylura timucu	Timucu
Mullets (mugilidae)	
Mugil curema	White Mullet
Great Barracuda (Sphyraenidae)	
Sphyraena barracuda	Great Barracuda
Threadfins (Polynemidae)	
Polydactilus virginicus	Barbu
Groupers (Surranidae)	
Epinephelus striatus	Nassau Grouper
Fairy Basslets (Grammidae)	
Fairy basslets	Gramma Loreto
Snook (Centropomidae)	
Centorpomus undecimalis	Snook
Halfbeaks (Hemiramphidae)	
Hemirampus balao	Balao
Jacks (Carangidae)	

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TABLE 5-11 Fish in the Mangrove of Naval Station Roosevelt Roads	
Caranx fusus	Blue Runner
Carans latus	Horse-eye Jack
Oligophlites saurus	Leather jacket
Snappers (Lutjanidae)	
Lutjamus apodus	Schoolmaster
Lutjamus jocu	Dog Snapper
Lutjamus mahogoni	Mahogany Snapper
Ocyurus chysurus	Yellowtail Snapper
Grunts (Pomadasydae)	
Haemulon sciurus	Bluestripped Grunt
Haemulon flavolineatun	French Grunt
Haemulon macrostomum	Spanish Grunt
Anisotremus virginicus	Porkfish
Porgies (Sparidae)	
Archosarqus rhomboidalis	Sea Bream
Mojarras (Gerreidae)	
Gerres cinereus	Yellowfin Mojarra
Eucinostomus lefroyi	Mottled Mojarre
Spadefish (Ephippidae)	
Chaetodlipterus faber	Spadefish
Scorpionfishes (Scorpaenidae)	
Scorpaena plumeri	Spotted Scorpionfish
Flying Gurnards (Dactylopteridae)	
Dactylopterus volitans	Flying Gunard
Butterflyfishes (Chaetodontidae)	
Chaetocion capistratus	Foureye Butterflyfish
Damselfishes (Pomacentridae)	

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TABLE 5-11 Fish in the Mangrove of Naval Station Roosevelt Roads	
Eupomacentrus fuscus	Dusky Danselfish
Eupomacentrus leucostictus	Beau Gregory
Abuclefcluf saxatillis	Sergeant Major
Wrasses (Labridae)	
Lachnollaimus maximus	Hogfish
Halichoeres burittatus	Slippery Dick
Halichoeres poeyi	Black-ear Wrasse
Thallasoma bifasciatum	Bluehead
Parrotfishes (Scaridae)	
Sparisoma rubrippine	Yellowtail Parrotfish
Sparisoma aurofrenatum	Redband Parrotfish
Scarus guacamaia	Rainbow Parrotfish

Source: Puerto Rico Department of Natural Resources

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TABLE 5-12

Birds of Naval Station Roosevelt Roads

1. Pied-billed Grebe, Podilymbus podicaps
   Red-billed Tropicbird, Phaethon aethereus (2)
   Brown Pelican, Pelecanus occidentalis (4)
   Brown Booby, Sula leucogaster

2. Magnificent Frigatebird, Fregata magnificens
   Great Blue Heron, Ardea herodias (3)
   Louisiana Heron, Hydranassa tricolor B
   Snowy Egret, Egretta thula B (3)
   Great Egret, Egretta alba B(3)

3. Green Heron, Butorides virescens B
   Little Blue Heron, Florida caerulea B
   Cattle Egret, Bubulcus ibis
   Least Bittern, Ixobrychus exilis B
   Yellow-crowned Night Heron, Nyctanassa violacea B

4. Black-crowned Night Heron, Nycticorax nycticorax (2)
   Bahama Pintail, Anas Bahamensis B (1)
   Blue-winged Teal, Anas discors
   American Widgeon, Anas americana
   Red-tailed Hawk, Buteo jamaicensis B

5. Osprey, Pandion haliaetus B (3)
   Merlin, Falco columbarious
   Clapper Rail, Rallus longirostris B
   American Coot, Fulica americana
   Caribbean Coot, Fulica caribaea B (3)

6. Common Gallinule, Gallinula chloropus B
   Piping Plover, Charadrius melodus
   Semipalmated Plover, Charadrius semipalmatus
   Black-bellied Ployer, Squatarola squatarola
   Wilson's Plover, Charadrius wilsonia B

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7. Killdeer, Charadrius vociferus B
   Ruddy Turnstone, Arenaria interpres
   Black-necked stilt, Himantopus himantopus B
   Whimbrel, Numenius phaeopus (2)
   Spotted Sandpiper, Actitis macularia

8. Semipalmated Sandpiper, Calidris pusilla
   Short-billed dowitcher, Limnodromus griseus (3)
   Greater Yellowlegs, Tringa melanoleuca
   Lesser Yellowlegs, Tringa flavipes
   Willet, Catoptrophorus semiplamatus (3)

9. Stilt Sandpiper, Micropalama himantopus
   Pectoral Sandpiper, Calidris melanotos
   Laughing Gull, Larus atricilla
   Royal Tern, Thalasseus maximus 92)
   Least Tern, Thalasseus maximus (2)

10. Sandwich Tern, Thalasseus sandvicensis (2)
    Bridled Tern, Sterna anaethetus
    Brown Noddy, Anous stolidus (5)
    White-winged Dove, Zenaida astatica B
    Zenaida Dove, Zenaida aurita B

11. White-crowned Pigeon, Columba leucocephala B (4)
    Mourning Dove, Zenaida macroura B
    Red-necked Pigeon, Columba squamosa
    Common Ground Dove, Columbina passerina B
    Bridled Quail Dove, Geotrygon mystacea

12. Ruddy quail Dove, Geotrygon montana
    Caribbean Parakeet, Aratinga pertinax
    Smooth-billed Ani, Crotophaga ani B
    Yellow-billed Cuckoo, Coccyzus americanus B
    Mangrove Cuckoo, Coccyzus minor B

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13. Short-eared Owl, Asio flammeus B (2)
    Chuck-will's Widow, Caprimulgus carolinensis
    Common Nighthawk, Chordeiles minor (5)
    Antillean Crested Hummingbird, Orthorhyncus cristatus B
    Green-throated Carib, Sericotes holosericeus B

14. Antillean Mango, Anthracothorax dominicus B
    Belted Kingfisher, Ceryle alcyon
    Gray Kingbird, Tyrannus dominicensis B
    Loggerhead Kingbird, Tyrannus caudifasciatus
    Stilid Flycatcher, Myriarchus stolidus

15. Caribbean Elaenia, Elaenia martinica
    Purple Martin, Progne subis
    Cave Swallow, petrochelidon fulva B
    Barn Swallow, Hirundo rustica
    Northern Mockingbird, Mimus polyglottos B

16. Pearly-eyed Thrasher, Margarops fuscatus B
    Red-legged Thrush, Mimocichla plumbea B
    Black-whishered Vireo, Vireo altiloquus B
    Prairie Warbler, Dendroica discolor
    American Redstart, Setophaga ruticilla

17. Yellow warbler, Dendroica petechia B
    Parula Warbler, Parula americana
    Magnolia Warbler, Dendroica magnolia
    Black and White Warbler, Mniotilta varia
    Cape May Warbler, Dendroica tigrina

18. Black-throated Blue Warbler, Dendroica caerulescens
    Adelaide's Warbler, Dendroica adelaidae
    Palm Warbler, Dendroica palmarum
    Ovenbird, Seiurus aurocapillus
    Northern Water Trush, Seirurus noveboracensis

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19. Bananaquit, Coereba flaveoia B
    Stripe-headed Tanager, Spindalis zena B
    Shiny Cowbird, Molothrus bonariensis B (4)
    Black-cowled Oriole, Jeterus dominicensis B
    Greater Antillean Grackle, Quiscalus niger B

20. Yellow-shouldered Blackbird, Angelaius xanthomus B (4)
    Hooded Mannikin, Lonchura cucullata B
    Yellow-faced Grassquit, Tiaris bicolor
    Ruddy Duck, Oxyura jamaicensis (3)

21. Peregrine Falcon, Falcon peregrinus (2)
    Marbled Godwit, Limosa fedoa (2)
    Puerto Rican Lizard Cuckoo, Saurothera vieilloti
    Prothonotary Warbler, Protonotaria citrea (1)

Addendum:Green-winged Teal, anas carolinensis

Data compiled by James W. Wiley, USDA Forest Service, Institute of Tropical Forestry, Rio Piedras, Puerto Rico, 1976. Symbols after species names are as follows: B = breeding; (1) = very endangered, (2) endangered, (3) on the verge of being endangered, (4) status undetermined, and (5) peripheral, according to Rare and Endangered Animal Species of Puerto Rico.

Source: U.S. Department of Agriculture, National Forest Service, 1976.

The station supports a variety of federally protected biota that have been listed pursuant to the Rare and Endangered Species Act of 1973. These species are presented in Table 5-15-13. The entire station has been designated as "critical habitat" for the Yellow-Shouldered Blackbird (Agelaius xanthomus). "Critical habitat" are areas considered vital to the continued existence and well-being of a given species. Yellow-shouldered blackbirds are endangered due to several factors, including contagious disease, lack of mangrove nesting areas free from rodent predation, and nest parasitization by other bird species (U.S. Fish and Wildlife, 1978).

Puerto Rico's major concentration of the West Indian manatees (Trichechus manatus) is found within the station's waters.

Marine turtles have been sighted by coral reefs and grassbeds. All marine turtles, except the green sea turtle, have been listed as rare and endangered (U.S. Fish and Wildlife, 1978).

The Puerto Rican boa (Epicrates inornatus) also takes refuge in the station's mangrove forests (U.S. Fish and Wildlife, 1978).

Hunting is not permitted on the station. Personnel are limited to shell collecting and fishing as consumptive uses of the station's natural resources. The naval station has also forbidden the harvesting of land crabs.

Plants, birds, insects, and fishes are all potential ecological receptors on the station; however, the pathways necessary to significantly impact the flora and fauna are not always complete, and exposure is not likely to occur. Although exposure is not likely to occur, remedial actions at the site will be directed towards minimizing adverse impacts to the flora and fauna encountered at the site. Site 15 makes up less than 1 percent of the total station area. Most vegetation was cleared from the site area when first constructed, and there has only been sparse revegetation by grasses, with some shrubs at the perimeter of the site. Most of the biota on the station would be found in the lusher areas of the station, especially in the mangrove forests, rather than on Site 15. Other than a few lizards and skinks, no animal populations were observed on Site 15 during the RI. It is felt that the reptile population would quickly reestablish itself following remediation. There are no surfacewater bodies present on the site. The drainage ditches on Site 15 only contain water immediately after a rainstorm, and consequently, do not support multicellular aquatic life. Sediment data from RR15SD07A and RR15SD07B indicate that it is unlikely that contamination of marine ecosystems above ARARs has occurred from discharge of the drainage swales to storm sewers.

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TABLE 5-13 Federally Listed Rare and Endangered Fauna	
Scientific Name	**Common Name**
Eretmochelys imbricata	Hawksbill turtle
Dermochelys coriacea	Leatherback turtle
Epicrates inornatus	Puerto Rican boa
Pelecanus occidentalis	Eastern brown pelican
Falco peregrinus anatum	American Peregrine Falcon
Columbia inornata wetmori	Puerto Rican plain pigeon
Agelaius xanthomus*	Yellow-shouldered blackbird
Trichechus manatus	West Indian manatee

*Entire Station has been designated "Critical Habitat" for the specie.

Source: U.S. Fish and Wildlife Service, DES, Mayaguez

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6.0 FEASIBILITY STUDY

The purpose of this feasibility study is to systematically screen technology alternatives to determine the overall best possible process to apply to polychlorinated biphenyl-contaminated (PCB-contaminated) soil and concrete located at Site 15 at NAVSTA Roosevelt Roads in Puerto Rico.

Sections 6.1 and 6.2 gives background information and introduces several important assumptions upon which the report is based. Section 6.3 discusses the available remedial technologies, screening criteria used to select appropriate technologies, and a description of the technologies remaining after the screening. Section 6.4 uses the information developed in Section 6.3 to draw conclusions and make recommendations about the site. Appendix E contains cost breakdown sheets, vendor file memos, and other background information.

The scope of the Feasibility Study was established using several key factors. These factors include the National Contingency Plan (NCP), OSWER Directive 9355.3-01, which specifies the process to be followed in conducting RI/FS work; and Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

6.1 Applicable or Relevant and Appropriate Requirements

Applicable or relevant and appropriate requirements (ARARs) are used to determine the extent of site cleanup, to scope and formulated remedial action alternatives, and to govern the implementation and operation of the selected action or actions. The NCP requires that remedial actions taken under the federal Comprehensive Environmental Response , Compensation, and Liability Act of 1980 (CERCLA) comply with all federal regulations that are applicable or relevant and appropriate to the remedial activities performed at the site unless specific waivers are granted by the EPA.

The remedial action selected under CERCLA Section 121(d) for NAVSTA Roosevelt Roads, Site 15 must comply with federal and territorial environmental laws that are either applicable or relevant and appropriate (ARAR). Applicable requirements are those standards, criteria, or limitations dictated under federal or state law that specifically address a hazardous substance, waste constituent, remedial action, location, or other circumstance at a CERCLA site. "Relevant and appropriate" requirements are those that are not "applicable", but still address problems or situations similar enough to those encountered at the site so that their use is well suited to that site.

Chemical-specific ARARs are health- or risk-based numeric values applied to site-specific conditions. These values establish a cut-off level for determining how much of a medium must be treated or removed. The ARAR assessment for this FS follows the protocols outlined in the August 8, 1988 interim final version of the US EPA guidance, CERCLA Compliance With Other Laws Manual and the August 1990, Guide on Remedial Actions at Superfund Sites with PCB contamination.

The Toxic Substances Control Act (TSCA) established cleanup levels for areas contaminated with PCBs. Policy promulgated after inception of TSCA requires clean-up of PCB-contaminated soil to different levels, depending upon the spill location, potential for exposure to residual PCBs remaining after clean-up, the concentration of the PCBs initially spilled, and the nature and size of the population potentially at risk of exposure. The potential ARAR for PCB in soil is 25 parts per million (ppm) where access control will be maintained. The 25 milligram per kilogram (mg/kg) limit is potentially relevant and appropriate for all sites. For PCB spill areas where there is a greater potential for human exposure to the contamination, the policy requires more stringent clean-up standards. The TSCA PCB regulations are presented below by spill location description:

Spill Location Description	PCB Criterion
Spills at outdoor electrical substations with restricted access	25-50 ppm
Spills at restricted access locations other than electrical substations	25 ppm
Spills at unrestricted access industrial areas	10 ppm

The soil contamination at Site 15 exists in an open area with unrestricted access to lawn maintenance and other station personnel; therefore, the 10-ppm cleanup standard is an ARAR for the site.

According to SARA, requirements may be waived by EPA under five specific conditions, provided that protection of human health and the environment is still ensured. The conditions under which waivers are permitted under SARA include the following:

- The selected remedial action is an interim remedy or portion of a total remedy which will attain the standard when complete;

- Compliance with such requirements will result in greater risk to human health and the environment than alternative options;

- Compliance with such requirements is technically impractical from an engineering perspective;

- The selected remedial action will provide an equivalent standard of performance using another approach; and

- The requirement is a state requirement that has been inconsistently applied.

6.2 Bases and Assumptions

In order to be able to develop and screen alternatives and receive information from vendors, several important assumptions or generalizations were made. It is important to note that the screening and cost quotes are based on these assumptions.

All of the alternative technologies considered in this report are cost-sensitive to the volume of contamination and are based on the assumption that the contamination is under this area and has not migrated extensively to other areas. This assumption is considered valid for shallow soil operable unit. Lateral migration in the subsurface must be assessed by an additional characterization during the implementation of the soil remedy. If it is later determined that the contamination has migrated, additional treatment of possibly large amounts of soil will be needed at additional expense.

The extent of contamination at Site 15 measures approximately 700 square yards (yd^2) (Figure 9); the volume of contamination is estimated to be approximately 235 cubic yards (yd^3) and is estimated to be 350 tons. This includes debris from cleaning of approximately 5,000 square feet of concrete surfaces at the site.

Where possible, vendor quotes were used for developing the costs for the various remedial alternatives. The vendor costs were developed based on previously noted assumptions used to characterize the contaminated site. If it later becomes apparent that these assumptions require revision, the costs associated with the various remedial alternatives will be similarly affected.

6.3 Screening and Analysis of Alternatives

Versar combined general response actions and the process options chosen to represent the various technology types for the contaminated soil and concrete to form viable, potentially effective site-wide remedial plans. Alternatives are developed and assembled to be consistent with remedial action objectives at the site. These remedial action objectives are based on the nine CERCLA criteria for evaluating and selecting remedial alternatives: overall protection of human health and the environment; compliance with applicable or relevant and appropriate requirements (ARARs); Long-term effectiveness and permanence; short-term effectiveness; reduction of mobility, toxicity, and volume; implementability; cost; local government acceptance; and community acceptance.

These evaluation criteria serve as the basis for performing the detailed analyses during the FS and for subsequently selecting an appropriate remedial action. A brief synopsis of each are presented below:

- Overall protection of human health and the environment. This provides a final check to assess whether each alternative adequately protects human health and the environment.

- Compliance with ARARs. This discusses whether alternatives will meet all Federal and State ARARs previously identified for the site. When an alternative does meet ARARs, then this criteria describes how it does. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA is discussed.

- Long-term effectiveness and permanence. This addresses the results of a remedial action in terms of the risk remaining at the site after remedial objectives are met. Any controls required to manage the risk posed by treatment residuals or untreated wastes are described.

- Reduction of toxicity, mobility, or volume through treatment. This criterion addresses the statutory preference for selecting remedial actions employing treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances.

- Short-term effectiveness. This criterion addresses the effects of the alternatives during the construction and implementation phase until remedial objectives are met. Alternatives are evaluated with respect to their effects

on human health and the environment, if applicable, during implementation of the remedial action.

- Implementability. The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Technical feasibility addresses construction and operational concerns and the reliability of technologies used. Administrative feasibility addresses activities needed to coordinate with Agencies (e.g., obtaining permits).

- Cost. This criterion addresses how total alternative costs, including capital and operation and maintenance (0&M) expenses, compare to one another.

- Local government acceptance. This criterion evaluates the technical and administrative issues and concerns that the State Agency may have regarding each of the remedial alternatives.

- Community acceptance. This assessment evaluates the issues and concerns that the public may have regarding each of the alternatives.

The universe of remedial technologies includes those that have been widely applied as standard construction techniques, as well as those that have been recently developed for specific remedial situations. In cases where a technology is commonly well understood (such as containment and removal response actions), extensive discussion is unnecessary. Where a technology is innovative or used in an "alternative" application (e.g., for waste treatment and disposal) more discussion is provided.

U.S. EPA guidance suggests that a single option can be selected for subsequent development and evaluation of alternatives where more than one process option exists for a technology (US EPA, 1988a). In some cases, this is a useful and valid approach (e.g., for the variety of common cover options). In other cases where a technology is more innovative, there may be only one available option or vendor. This is particularly true of treatment technologies specific to a particular waste constituent. In these situations, the option is more fully reviewed prior to screening. Table 6-1 summarizes remedial technologies and process options identified for potential application at Site 15.

TABLE 6-1: IDENTIFICATION AND PHASE ONE SCREENING OF REMEDIATION ALTERNATIVES

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
NO ACTION	NONE	NOT APPLICABLE	REQUIRED FOR CONSIDERATION BY NCP	NOT FEASIBLE. DOES NOT REDUCE MOBILITY, TOXICITY, OR VOLUME OF CONTAMINANT.
INSTITUTIONAL ACTIONS	ACCESS RESTRICTIONS	DEED RESTRICTIONS	DEEDS FOR SITE PROPERTY WOULD RESTRICT POSSIBLE SITE USES AND DEVELOPMENT.	POTENTIALLY FEASIBLE.
		FENCE SITE	INSTALL SECURITY FENCING AROUND THE SITE.	POTENTIALLY FEASIBLE.
CONTAINMENT	CAPPING	ASPHALT	LAYER OF ASPHALT IS SPRAYED OVER THE SITE.	NOT FEASIBLE. GROUNDWATER COULD STILL LEACH CONTAMINANTS FROM SOIL. DOES NOT REDUCE MOBILITY, TOXICITY, OR VOLUME OF CONTAMINANT.
		CONCRETE	CONCRETE SLAB IS INSTALLED OVER THE SITE.	
		CLAY/SOIL	COMPACTED CLAY AND VEGETATIVE COVER OVER THE SITE.	
REMOVAL, TRANSPORTATION, AND OFF-SITE TREATMENT OR DISPOSAL	TREATMENT OR DISPOSAL OF EXCAVATED AND TRANSPORTED WASTE	PERMITTED LANDFILL	TRANSPORT UNTREATED SOILS TO A PERMITTED LANDFILL.	POTENTIALLY FEASIBLE. MAY REQUIRE PRETREATMENT OF SOILS.
		THERMAL TREATMENT FACILITY	TRANSPORT UNTREATED SOILS TO AN INCINERATION FACILITY FOR PROCESSING.	POTENTIALLY FEASIBLE.

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TABLE 6-1: IDENTIFICATION AND PHASE ONE SCREENING OF REMEDIATION ALTERNATIVES CONTINUED

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
ON-SITE SOIL TREATMENT	BIODEGRADATION	COMPOSTING	CONTAMINATED SOILS ARE PLACED IN A CONTROLLED ENVIRONMENT WITH ADDITION OF HEAT AND AIR TO AID MICROBIAL DEGRADATION OF ORGANICS.	NOT FEASIBLE FOR PCB CONTAMINATION AT SITE 15
		SOLID PHASE TREATMENT	CONTAMINATED SOILS ARE TREATED IN AN ABOVE-GRADE SYSTEM USING CONVENTIONAL SOIL MANAGEMENT PRACTICES TO ENHANCE MICROBIAL DEGRADATION OF ORGANICS.	
		SLURRY PHASE TREATMENT	CONTAMINATED SOILS PLACED IN A MOBILE BIOREATOR IN A SLURRY FORM. SLURRY IS MECHANICALLY AGITATED IN THE REACTOR TO MAINTATHE APPROPRIATE ENVIRONMENTAL CONDITIONS FOR MICROBIAL DEGRADATION OF ORGANICS.	
		IN SITU BIODEGRADATION	INDIGENOUS OR INTRODUCED AEROBIC OR ANAEROBIC BACTERIA ARE INTRODUCED TO CONTAMINATED SOILS TO BIODEGRADE ORGANIC COMPOUNDS. NATURAL BIODEGRADATION PROCESS IS ENHANCED BY INJECTING NUTRIENTS.	
	PHYSICAL/CHEMICAL TREATMENT	SOIL WASHING	USE OF WATER, STEAM, OR SOLVENT-BASED SOLUTION TO WASH OR VOLATILIZE AND FLUSH CONTAMINANTS FROM SOIL. OPERATION PERFORMED IN A CONTACTOR.	NOT FEASIBLE FOR PCB CONTAMINATION
		IN-SITU VAPOR EXTRACTION	REMOVAL OF VOLATILE ORGANIC COMPOUNDS BY APPLICATION OF VACUUM ON SYSTEM THROUGH A SYSTEM OF WELLS.	NOT FEASIBLE FOR PCB CONTAMINATION
		EMERGING TECHNOLOGIES DECHLORINATION (e.g., KPEG, LARC PROCESSES) SOLVENT EXTRACTION (e.g., ACUREX) BIOREMEDIATION (e.g., BIO CLEAN) PYROLYSIS (e.g., ADVANCED ELECTRIC REACTOR) VITRIFICATION (e.g., BATELLE PACIFIC PROCESS	VARIOUS NOVEL TREATMENT PROCESSES	PROCESSES FOR PCB SOILS HAVE NOT BEEN COMMERCIALLY DEVELOPED. THE KPEG PROCESS, BASED ON A NUCLEOPHILC SUBSTITUTION FOR CHLORINE ATOMS, HAS BEEN SUCCESSFULLY PILOT-TESTED, BUT HAS NOT BEEN SCALED UP. THE LARC PROCESS, WHICH USES RADIANT ENERGY TO DECHLORINATE THE BIPHENYL COMPOUND, HAS ONLY BEEN SUCCESSFULLY DEMONSTRATED IN THE LABORATORY. EXCEPT FOR THE ADVANCED ELECTRIC REACTOR (AER) PYROLYSIS PROCESS, THE EMERGING TECHNOLIGIES FOR PCB WASTES HAVE NOT BEEN DEMONSTRATED, AND ARE IN VARIOUS STAGES OF DEVELOPMENT FROM LABORATORY-SCALE THROUGH FIELD TESTS. ALTHOUGH THE AER PROCESS IS PERMITTED UNDER TSCA BY EPA REGION VI, THE FINAL SYSTEM DESIGN STILL MUST BE DETERMINED FROM ADDITIONAL DATA, AND THERE IS NO AVAILABLE COMMERCIAL CAPACITY FOR TREATMENT USING THIS PROCESS.
	THERMAL TREATMENT	ON-SITE ROTARY KILN INCINERATION	COMBUSTION OF SOLIDS IN A MOBILE HORIZONTALLY ROTATING CYLINDER DESIGNED FOR UNIFORM HEAT TRANSFER.	POTENTIALLY FEASIBLE, HOWEVER, VENDORS WERE EXTREMELY RELUCTANT TO REMIDIATE LESS THAN 5000 CUBIC YARDS. COST IS VERY HIGH FOR SMALL QUANTITIES.
		LOW TEMPERATURE THERMAL TREATMENT	SOIL IS FED INTO HEATED SCREW AUGER. CONTAMINANTS ARE GENERALLY VAPORIZED AND RECOVERED	NOT FEASIBLE FOR PCB CONTAMINATION. PCB'S ARE NOT VOLATILE ENOUGH.

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U.S. EPA guidance specifies that screening be performed on the basis of "effectiveness" and "implementability" (US EPA 1988a). Consistent with this guidance, the screening process for this feasibility study considers the following requisite conditions:

- This technology must be demonstrated at, or approaching, full scale on actual waste materials for the constituent of concern (PCBs), and

- The technology must be commercially available at the time of FS preparation, i.e., at least one vendor must be prepared to enter into a contract for providing the necessary equipment and processing.

Technologies that did not meet both of these conditions were screened from further consideration.

Some of the technologies that pass the screening could require treatability studies to determine important treatment parameters. While a specific technology may appear reasonable based on past experience, its use may require verification because of site-specific or other conditions.

Treatability testing satisfies a number of purposes. The most important is to ensure that the technology is appropriate for the site and constituent or constituents of concern; in this case, PCBs. Another purpose for testing is the development of the necessary design parameters. During the remedial design phase, a site-specific design is developed at the bench, pilot, or field scale. These parameters facilitate proper sizing of units and generate measures of effectiveness to ensure that the design is efficient and cost effective.

The retention of any particular technology does not necessarily mean that it will be applicable to the site. The screening process eliminates technologies that have a low probability of being successfully applied at the site to meet the site requirements.

The screening and evaluation of process options is performed in two phases. The first phase consists of identifying potentially applicable process options and technology types, and evaluating these options with respect to technological implementability. During this phase, options were screened based on site characteristics, contaminant types and concentrations, and technology constraints. Those options that could not be effectively implemented were screened out from further evaluation.

The second phase consists of further evaluation of the alternatives that were considered to be implementable based on the first evaluation and screening phase. Within technology

type the effectiveness, implementability, and cost are further evaluated and compared to one another. Emphasis is placed on the effectiveness of the options. Where possible, one representative option is selected for further evaluation from each technology type. The following sections present the screening an evaluation of process options for Site 15, NAVSTA Roosevelt Roads. Detailed descriptions are presented in the Phase II discussion.

Alternatives were eliminated from consideration during Phase I and Phase II screening for the following reasons: technology not proven at or near full scale; technology not feasible; technology not applicable, not demonstrated, or not commercially available for testing or destroying PCB solid waste; or technology potentially applicable, but requires extensive site characterization and successful laboratory or pilot field tests to demonstrate viability. Care was taken to ensure that the surviving technologies did not require restrictions on future land use, and did not require a continuing operations and maintenance (O&M) program.

It is noted here that although the screening of technologies was is limited to remediation of PCB-contaminated soils. There are approximately 10,000 ft^2 of PCB-contaminated concrete walls and floors in Building 90 to be remediated. Technologies associated with the remediation of the concrete were not explicitly subject to a feasibility study because the residue can effectively be considered to require the same treatment/disposal considerations as soil. Remediation of the concrete will be effected via gritblasting, scarification/chipping, and powerwashing of the concrete surfaces in and around Building 90.

Gritblasting involves the spray application of an abrasive material to concrete surfaces to effectively erode the contaminated material. This technique is most effective when contamination has penetrated less than 2 inches into the concrete.

Scarification/chipping, which could be necessary if penetration is beyond two inches, employs pneumatically-operated piston heads to remove up to 3 inches of the surface of contaminated brick or concrete. This technique is particularly effective when the contamination has penetrated more than 1/4 inch into the surface of the material, as it has done due to long-term contact with the floor. Upon completion of the scarification/chipping and gritblasting, the residual dust and contamination-laden debris is vacuumed from the surfaces, packed in appropriate containers for disposal, and is treated in the same manner as the contaminated soil. After the scarification/chipping process, the remediated part of the floor will require rebuilding and refinishing. Powerwashing is accomplished with high-pressure water equipment. A surface acting agent, called a surfactant is applied to the concrete. The role of the surfactant is to suspend the PCB-containing particles and prevent them from being driven deeper into the concrete. A high pressure jet of water is directed at the concrete to blast the PCB-contaminated dirt particles from the surface. This technique is effective for

walls and surfaces where the depth of PCB penetration is less than one inch. The contaminated effluent from the powerwashing operation is collected and run through granular activated carbon canisters which adsorb the PCB-contaminated particles. The canisters are disposed as PCB-contaminated waste in a similar manner as contaminated soil from the site.

6.3.1 Phase I Screening of Potential Alternatives

Table 6-1 presents the results of the Phase I screening of available process options for the PCB contamination at Site 15. Included in the table are general response actions, associated remedial technologies and process options, descriptions of the options, and the associated screening comments. Most technologies are potentially applicable to the PCB contamination at the site; however, determining whether these technologies are definitely applicable or not applicable would in some cases require extensive hydrogeologic characterization, or pilot studies, or both. Performing these characterizations or pilot tests may not prove justifiable in light of the added costs associated with these processes, with no additional effectiveness compared to other technologies.

6.3.2 Phase II Screening of Process Options

Table 6-2 presents the results of the Phase II screening of available process options for the PCB contamination at Site 15. Included in the table are general response actions, remedial technology, process options, and the evaluation of the process options concerning effectiveness, implementability, and relative cost.

Three remedial alternatives survived Phase II screening: Alternative A represents transportation to an approved incineration facility for thermal destruction of PCB-contaminated soil; Alternative B represents transportation to an approved landfill facility for land disposal; and Alternative C represents soil excavation, followed by on-site incineration of PCB-contaminated soil.

6.3.3 Detailed Analysis of Alternatives

After the phase-one and phase-two screening evaluations were performed on the universe of potentially applicable remedial technologies, three process options carried forward into detailed analysis: Alternative A- Excavation and transportation to an approved incineration facility for PCB-contaminated soil and incineration; Alternative B-Excavation and transportation to an approved Landfill facility; and Alternative C- Soil excavation, followed by on-site incineration of PCB-contaminated soil.

TABLE 6-2: PHASE TWO SCREENING OF REMEDIATION ALTERNATIVES

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	SCREENING CRITERIA: EFFECTIVENESS	SCREENING CRITERIA: IMPLEMENTABILITY	SCREENING CRITERIA: COST	
INSTITUTIONAL ACTIONS	ACCESS RESTRICTIONS	DEED RESTRICTIONS	NOT EFFECTIVE. REQUIRES RESTRICTIONS ON FUTURE SITE USE. DOES NOT REDUCE MOBILITY, TOXICITY, OR VOLUME OF CONTAMINANT.	EASILY IMPLEMENTABLE.	NONE.	
REMOVAL, TRANSPORTATION, AND OFF-SITE TREATMENT OR DISPOSAL	TREATMENT OR DISPOSAL OF EXCAVATED AND TRANSPORTED WASTE	PERMITTED LANDFILL	VERY EFFECTIVE. LEAVES RESIDUAL LIABILITY IF LANDFILL CLOSES.	MODERATELY EASILY IMPLEMENTED. REQUIRES TRANSPORTATION OF 1600 TONS OF SOIL BY BARGE.	EXCAVATION TRANSPORTATION DISPOSAL BACKFILL TOTAL:	3/TON 400/TON 296/TON 10/TON 709/TON
		INCINERATION FACILITY	VERY EFFECTIVE.	MODERATELY EASILY IMPLEMENTED. REQUIRES TRANSPORTATION OF 1600 TONS OF SOIL BY BARGE.	EXCAVATION TRANSPORTATION DISPOSAL BACKFILL TOTAL:	3/TON 400/TON 2000/TON 10/TON 2413/TON

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The detailed analysis of alternatives consists of the evaluation and presentation of the relevant information needed to select a site remedy. In the detailed analysis, each alternative is assessed against the nine CERCLA evaluation criteria described previously. The results of this assessment are arrayed to compare the alternatives and identify the key tradeoffs among them. This approach to analyzing alternatives provides sufficient information to adequately compare the alternatives, select an appropriate remedy for the site, and demonstrate satisfaction of the CERCLA remedy selection requirements.

The specific statutory requirements for remedial actions which must be supported by this report for Site 15 are listed below. The alternative must:

- Be protective of human health and the environment
- Attain ARARs (or provide grounds for invoking a waiver)
- Be cost-effective
- Utilize permanent solutions and alternative treatment technologies to the maximum extent practicable
- Satisfy the preference for treatment that reduces the toxicity, mobility, or volume, or provide an explanation as to why it does not.

In addition, Section 121(b)(1)(A) of CERCLA emphasizes evaluation of long-term effectiveness and related considerations for each of the remedial alternatives.
Below are the detailed descriptions of the three remaining alternatives. Although institutional controls are screened out as a stand alone remediation, such controls will be necessary with the remaining remedies to ensure that the sites will remain an industrial area. A 10-ppm ARAR has been applied based on the site's use for industrial purposes. Residential use would require a cleanup to 1 ppm (EPA, 1990b).

6.3.3.1 Alternative A - Excavation, Transportation, and Incineration

This remedial alternative is applicable to PCB-contaminated soil and coral at Site 15 which has total PCB concentrations greater than 10 ppm. An estimated total of 235 cubic yards of PCB-contaminated soil at the site require remediation. The excavation and transportation to incineration facility remedial alternative involves the removal of the contaminated soil using conventional construction techniques (e.g., backhoe or track-mounted excavator). All soil measuring above 10 ppm PCBs is excavated and replaced with clean

backfill. After the contaminated soil is excavated, the material is loaded into intermodal containers and placed on barges for transportation to Corpus Christi, Texas. There, the manifested wastes are then transported via rail to Las Vegas, Nevada, and transferred to trucks for transportation to the incineration facility. The properly licensed facility is U.S. Ecology in Beaty, Nevada. There are no incineration facilities in Puerto Rico that are properly licensed to receive PCB-bearing waste. U.S. Ecology is the nearest facility. Off-site incineration in accordance with 40 CFR 761 as it pertains to incineration of PCB solids is effected by subjecting the wastes to very high temperatures at which the contaminants are oxidized to carbon dioxide, water, and chlorine gas, which is recovered. Any noncombustibles in the contaminated soil will appear as ash residue in the incineration process, and will require disposal by landfilling.

Assessment of Alternative A

This remedial alternative will adequately protect human health and the environment from PCBs associated with contaminated soil. Soils and the underlying coral contaminated above 10 ppm, the established clean-up standard for soil at the site, will be excavated, thereby removing the contaminant source.

Compliance with ARARs will be attained because (1) all materials contaminated with PCBs at concentrations above 10 ppm will be removed from the site for incineration, and (2) the removed soils will be incinerated according to requirements of the facility's TSCA permit for PCB destruction.

Excavating PCB-contaminated soils is an appropriate way to eliminate the major source of continued PCB migration from a soil to the subsurface environment. PCBs will drain from a soil saturated with PCB under the force of gravity until residual saturation is reached. At residual saturation, no additional fluid migration will occur unless precipitation washes PCB from the soil profile. It is the characteristics of the soil that determine its capacity to retain PCB in liquid and gaseous phases under saturated and unsaturated conditions. Excavation of soils at residual saturation can effectively remove product from the environment, if the soil is of a type that can retain large amounts of product. It is the finer-textured sands like the soil at Site 15 that are most effectively excavated, because these soils retain the most PCBs.

After the removal of PCB-contaminated soil, no residual contamination levels above 10 ppm will be present in the remaining soil. Consequently, no future remedial controls will be required to monitor and maintain the long-term effectiveness of this remedial alternative for all known contamination at the property.

This alternative will significantly reduce the toxicity and volume of the contaminated media. Theoretically, all PCBs will undergo complete combustion to yield carbon dioxide and water. Any products of incomplete combustion will be captured and removed from the stack gas by an air pollution control system. Any wastewater streams containing by-products of the incineration process also will be treated prior to discharge. Noncombustibles will carry through the process and exit as solid waste ash, which could then be disposed in a landfill.

Provided that workers performing soil excavation at the property are properly equipped with personal protective equipment and are fully certified for hazardous waste work (according to OSHA regulations in 40 CFR 1910), implementation of this alternative should not pose a risk to human health or the environment. As a precautionary measure, the soils could be kept saturated at all times during excavation work, thereby minimizing release of possibly-contaminated dust particles.

This remedial alternative is moderately easy to implement. Equipment and labor required for the excavation work are available in Puerto Rico or are easily transported to the site. OSHA-certified workers are required for the work, but they are also available in Puerto Rico or the United States. Clean backfill is available on the island of Puerto Rico and is relatively inexpensive.

This alternative should be acceptable to the local regulatory agencies and the local community. The contaminated soil will be permanently removed from the property, thereby eliminating any significant risk to human health and the environment associated with exposure to PCB contaminated soil. The material will be properly managed and ultimately destroyed according to applicable regulations. Also, the remedial action could be implemented within a relatively short time period, thereby not restricting future development or use of the site.

Factors found to affect costs of excavation/removal, transportation, and disposal are:

A. Excavation or on-site transfer:
   1. Excavation depth
   2. Site surface characteristics
   3. Health and safety requirements
   4. Material
   5. Waste quantity

B. Transportation
   1. Distance to disposal facility
   2. Accessibility to road

3. Material type and quantity

C. Disposal
1. Material type and quantity

The excavation depth for the soil on this site is only 1 to 2 feet, which makes it very easy to reach all of the contaminated soil without necessitating large, expensive earth-working equipment. The site is generally a flat, wide open area with few obstructions. These factors work in favor of reducing the cost for excavation. Working against low cost is the Level C personal protective equipment needed by the ground crew during removal activities due to the elevated levels of PCBs in the soil, which reduces efficiency by about 50 percent. Also adding greatly to the cost is the large expense of incineration. Affecting transportation costs, the material is to be transported to Nevada and requires travel by barge, rail, and trucks. Working in favor of lower costs, the material is easy to handle, and site is easily accessible.

Remedial cost estimates and vendor information are contained in Appendix E. Costs for Alternative A are as follows: Excavation of the soil via backhoe is priced on a per day basis at about $1,000 per day. Approximately 300 tons can be loaded in a day, putting the per-ton price at about $3 per ton. Transportation to the licensed incineration facility in Beaty, Nevada was quoted at $500 per ton. Incineration at the facility is expected to cost about $1 per pound, or $700,000 for 350 tons. Replacing backfill in the hole will cost $10 per ton. Cost for gritblasting and powerwashing of the concrete walls and floors is estimated to be $5,000. The capital cost including QA/QC for Alternative A is $928,778. Adding costs for engineering design (15 percent), construction management (15 percent), startup (10 percent), bonds and permits (2.5 percent), legal fees (3 percent), and unforeseen contingencies (20 percent) brings the total capital cost for this alternative to $1,490,688. It is noted here that the cost is based on remediation of Sites 15 and 16 at NAVSTA Roosevelt Roads concurrently. If only one site were to be remediated at one time, the per-ton cost would be expected to be higher. However, the cost variance would not be expected to affect the selection of remedy.

Because all contaminated soil will be removed, no future operation and maintenance costs will be incurred as a result of this remedial alternative.

6.3.3.2 Alternative B - Excavation, Shipment, and Landfill Disposal

This remedial alternative is applicable to PCB-contaminated soil and underlying coral at Site 15 which has total PCB concentrations greater than 10 ppm. An estimated total of 235 cubic yards of PCB-contaminated soil at the site require remediation.

The excavation and transportation to landfill facility remedial alternative involves the removal of the contaminated soil using conventional construction techniques (e.g., backhoe or track-mounted excavator). All soil or coral measuring above 10 ppm PCBs is excavated and replaced with clean backfill. After the contaminated soil is excavated, the material is loaded into internodal containers and placed on barges for transportation to Corpus Christi, Texas. There, the manifested wastes are then transported via rail to Las Vegas, Nevada, and transferred to trucks for transportation to the landfill facility. The properly licensed facility is U.S. Ecology in Beaty, Nevada. There are no landfills in Puerto Rico that are licensed to receive PCB-bearing wastes. U.S. Ecology is the nearest properly licensed facility. The contaminated wastes are to be properly landfilled at the facility.

Assessment

This remedial alternative will adequately protect human health and the environment from PCBs associated with contaminated soil. Soils or coral contaminated above 10 ppm, the established clean-up standard for soil at the site, will be excavated, thereby removing the contaminant source.

Compliance with ARARs will be attained because (1) all materials contaminated with PCBs at concentrations above 10 ppm will be removed from the site for pretreatment and landfilling, and (2) the removed soils will be pretreated and landfilled according to requirements of the facility's TSCA or RCRA permit for PCB treatment and disposal.

After the removal of PCB-contaminated soil, no residual contamination levels above 10 ppm will be present at the site. Consequently, no future remedial controls will be required to monitor and maintain the long-term effectiveness of this remedial alternative for all known contamination at the site.

This alternative will significantly reduce the remaining contaminant volume by removing all soil contaminated above 10 ppm total PCB concentration. However, regardless of the pretreatment method employed, the waste toxicity may or may not be reduced prior to landfilling. Therefore, potential future liabilities associated with the disposal of the pretreatment waste material in a landfill may exist.

Provided that workers performing soil excavation at the property are properly equipped with personal protective equipment and are fully certified for hazardous waste work (according to OSHA regulations in 40 CFR 1910), implementation of this alternative should not pose a risk to human health or the environment. As a precautionary measure, the soils should be

kept saturated at all times during excavation work, thereby minimizing release of potentially-contaminated dust particles.

This remedial alternative is moderately easy to implement. Equipment and labor required for the excavation work are available in Puerto Rico or are easily transported to the site. OSHA-certified workers are required for the work, but they are also available in Puerto Rico or the United States. Clean backfill is available on the island of Puerto Rico and is relatively inexpensive.

This alternative should be acceptable to the local regulatory agencies and the local community. The contaminated soil will be permanently removed from the site, thereby eliminating any significant risk to human health and the environment associated with exposure to PCB-contaminated soil. The material will be properly managed and ultimately disposed according to applicable regulations. Also, the remedial action could be implemented within a relatively short time period, thereby not restricting future development and use of the site.

It is conservatively assumed that all PCB soil removed from Site 15 will require some type of pretreatment prior to acceptance for landfilling at the licensed facility. Measured levels of PCBs (as Aroclor 1260) in soil samples from the property were generally below 500 ppm. However, "hot spots" in the soil are possible, and any batch shipment of excavated soils from the site may be subject to federal restrictions on landfilling TSCA waste.

Factors found to affect costs of excavation/removal, transportation, and disposal are:

A. Excavation or on-site transfer:
   1. Excavation depth
   2. Site surface characteristics
   3. Health and safety requirements
   4. Material
   5. Waste quantity

B. Transportation
   1. Distance to disposal facility
   2. Accessibility to road
   3. Material type and quantity

C. Disposal
   1. Material type and quantity

The excavation depth for the soil on this site is only 1 to 2 feet, which makes it very easy to reach all of the contaminated soil without necessitating large, expensive earth-working equipment. The site is generally a flat, wide open area with few obstructions. These factors work in favor of reducing the cost for excavation. Working against low cost is the Level C personal protective equipment needed by the ground crew during removal activities due to the elevated levels of PCBs in the soil, which reduces efficiency by about 50 percent. Affecting transportation costs, the material is to be transported to Nevada and requires travel by barge, rail, and trucks. Working in favor of lower costs, the material is easy to handle, and site is easily accessible.

Remedial cost estimates and other vendor information are contained in Appendix E. Costs for Alternative B are as follows: Excavation of the soil via backhoe is priced on a per day basis at about $1,000 per day. Approximately 300 tons can be loaded in a day, putting the per ton price at about $3 per ton. Transportation to and disposal at the licensed landfill facility in Beaty, Nevada was quoted at $696 per ton. Backfill for the hole costs $10 per ton. Cost for powerwashing and gritblasting of the concrete walls and floors is estimated to be $5,000. The capital cost for Alternative B, including QA/QC, is $265,808. Adding costs for design (15 percent), construction management (15 percent), startup (10 percent), bonds and permits (2.5 percent), legal fees (3 percent), and unforeseen contingencies (20 percent) brings the total capital cost for this alternative to $426,621. It is noted here that the cost is based on remediation of Sites 15 and 16 concurrently. If only one site were to be remediated at one time, the per-ton cost is expected to be higher. However, the cost variance would not be expected to affect the selection of remedy.

Because all contaminated soil will be removed, no future operation and maintenance costs will be incurred as a result of this remedial alternative.

6.3.3.3 Alternative C - Soil Excavation and On-site Incineration

This remedial alternative is applicable to PCB-contaminated soil or the underlying coral at Site 15 which has total PCB concentrations greater than 10 ppm. An estimated total of 235 cubic yards of PCB-contaminated soil at the site require remediation.

The excavation and on-site incineration remedial alternative involves the excavation of the contaminated soil using conventional construction techniques (e.g., backhoe or track-mounted excavator). All materials measuring above 10 ppm PCBs is excavated and replaced with clean backfill. After the contaminated soil is excavated, the material is loaded into a mobile incineration trailer for thermal destruction. The contaminated soil is subjected to extremely high temperatures where it breaks down into carbon dioxide, water, and chlorine

gas, which is collected from the exhaust before it can enter the atmosphere. Any noncombustible materials in the contaminated soil will appear as ash residue in the incineration process, and will require disposal by landfilling.

Assessment

This remedial alternative will adequately protect human health and the environment from PCBs associated with contaminated soil or underlying coral. Soil or coral contaminated above 10 ppm, the established clean-up standard for soil at the site, will be excavated, thereby removing the contaminant source.

Compliance with ARARs will be attained because all material contaminated with PCBs at concentrations above 10 ppm will be excavated, incinerated, and returned to the ground as clean fill. Cleanup efficiency for on-site incineration is equivalent to that of off-site incinerators.

After the incineration and replacement of the soil, no residual contamination levels above 10 ppm will be present at the site. Consequently, no future remedial controls will be required to monitor and maintain the long-term effectiveness of this remedial alternative for all known contamination at the site. This alternative will significantly reduce the remaining contaminant volume by removing all soil contaminated above 10 ppm total PCBs concentration.

Provided that workers performing soil excavation at the property are properly equipped with personal protective equipment and are fully certified for hazardous waste work (according to OSHA regulations in 40 CFR 1910), implementation of this alternative should not pose a risk to human health or the environment. As a precautionary measure, the soils should be kept saturated at all times during excavation work, thereby minimizing release of potentially-contaminated dust particles.

This remedial alternative is extremely difficult to implement. At the time of this writing, no vendor was willing to quote a price on the relatively small amount of soil at the site. OSHA-certified workers are required for the work and they are available in Puerto Rico or the United States.

This alternative should be acceptable to the local regulatory agencies and the local community. However, local citizens are often greatly concerned by on-site incineration programs. The contaminated soil or coral will be permanently reduced in toxicity, thereby eliminating any significant risk to human health and the environment associated with exposure

to PCB-contaminated soil. The material will be properly managed and ultimately disposed according to applicable regulations. Also, the remedial action could be implemented within a relatively short time period, thereby not restricting future development and use of the site.

The excavation depth for the soil on this site is only 1 to 2 feet, which makes it very easy to reach all of the contaminated soil without necessitating large, expensive earth-working equipment. The site is a flat, wide open area with few obstructions. These factors work in favor of reducing the cost for excavation. Working against low cost is the Level C personal protective equipment needed by the ground crew during removal activities due to the elevated levels of PCBs in the soil, which reduces efficiency by about 50 percent. Additionally, the cost of on-site incineration is extremely expensive due to the limited number of companies willing to do the incineration. Working in favor of lower costs, the material is easy to handle, and site is easily accessible.

Remedial cost estimates and vendor information is contained in Appendix E. Costs for Alternative C would be as follows: Excavation of the soil via backhoe is priced on a per day basis at about $1,000 per day. Approximately 300 tons can be loaded in a day, putting the per-ton price at about $3 per ton. Incineration is expected to cost approximately $2,000 per ton, or $700,000. Cost for powerwashing and gritblasting of the concrete walls and floors is estimated to be $5,000. The capital cost including QA/QC for Alternative C is $741,353. Adding costs for engineering design (15 percent), construction management (15 percent), startup (10 percent), bonds and permits (2.5 percent), legal fees (3 percent), and unforeseen contingencies (20 percent) brings the total capital cost for Alternative C to $1,189,871. It is noted here that the cost is based on remediation of Sites 15 and 16 at NAVSTA Roosevelt Roads concurrently. If only one site were to be remediated at one time, the per-ton cost would be expected to be higher. However, the cost variance is not large enough to affect the selection of remedy.

Because all contaminated soil will be treated and replaced when clean, no future operation and maintenance costs will be incurred as a result of this remedial alternative.

6.4 Discussion and Conclusions

Potential remedial technologies have been described and screened. The following is an analysis of the findings presented in the preceding sections and recommendations based on the analysis.

Three remedial alternatives remain after the screening:

- Alternative A - soil excavation, transportation, and off-site incineration,
- Alternative B - soil excavation, transportation, and off-site land disposal, and
- Alternative C - soil excavation and on-site incineration.

The alternatives were screened according to effectiveness, implementability, and other pertinent criteria designed to determine suitability of each alternative to the remediation goal. Cost was used as the final determinant, but only if all other criteria were equal between multiple alternatives.

Based on this feasibility study, Alternative B - Excavation, Shipment, and Landfill Disposal is the remedial technology recommended for Site 15. This process option was selected based on probable achievement of the nine CERCLA criteria for selecting remedial alternatives: overall protection of human health and the environment; compliance with applicable or relevant and appropriate requirements (ARARs); long-term effectiveness and permanence; short-term effectiveness; reduction of mobility, toxicity, and volume; implementability; cost; local government acceptance; and community acceptance. The total cost for this alternative is estimated to be $426,621.

Alternative A met the criteria for alternatives and promised to be equally effective for remediation of the site. Alternative A has a decreased liability in the long run, due to the elimination of contaminated soil, rather than the landfilling of it. The cost for Alternative A is prohibitively expensive compared to Alternative B, $1,490,688 compared to $426,621. The reduced cost for Alternative B is more than compensatory for the increased potential liability.

Alternative C is equally effective as Alternative B. It has the added advantages of decreased potential liability and elimination of the need for backfill at the site, since the incinerated soil is replaced in the ground. The cost for on-site incineration was quoted between $600 to $2,000 per ton. If a contract could be secured at the lower figure, on-site incineration would be almost the same cost as Alternative B, but would be more desirable due to its previously noted inherent advantages. Unfortunately, no vendor was willing to quote on jobs of less than 5,000 tons. This option should be reviewed at the time of remediation, since the field of remediation is growing at a rapid pace and a contractor may be found who is willing to undertake remediation of the site in the future.

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APPENDIX A

Chain of Custody Records
and Data Validation Reports
for May 1991 Samples

Versar INC.

MEMORANDUM

TO: Noel Simmons

FROM: Justine Alchowiak

DATE: September 6, 1991

SUBJECT: Data Validation for Roosevelt Road

Attached are the results of the data validation completed for Roosevelt Road. A summary of the data validation was completed for each batch of analytical data. The data were reviewed for the following items:

- Holding time
- Calibration
- Blanks
- Surrogate recoveries
- Matrix spike/matrix spike duplicate recovery
- Field duplicates
- Compound identification and quantification

An assessment of the data usability was also completed.

Data Validation
Versar Control No. 4774, B #1
Sediments

The following field numbers are included in B #1:

Field Number	Surrogate Recovery Outside Range (60-140%)
Laboratory Batch 1	
RR16SD09DL2 (1/100)	X
RR16SD09MS	X
RR16SD09MSD	X
RR16SD10DL2 (1/100)	X
RR16SD11DL (1/10)	X
RR16SD12	X
RR16SD01	X
RR16SD02	X
RR16SD03	X
RR16SD04	X
RR16SD05DL (1/10)	X
RR16SD06DL (1/10)	X
RR16SD07	X
RR16SD08DL (1/10)	X
RR16SD08DDL (1/10)	X
RB0385 (Reagent Blank)	
MSTD50052 (Method Standard)	X
Laboratory Group 2	
RR15CO2DL (1/10)	X
RR15CO1	X
RR16CO2	X
RR16CO3	X
RR16CO4DL3 (1/1000)	X
RR16CO5DL2 (1/100)	X
RR16CO6	X
RB0383	
MSTD50014	X
RR15CO2MS	X
RR15CO2MSD	X
Laboratory Group 3	
RR16CO1	X
RB0419	
MSTD50057	X

Holding Time	All samples were extracted and analyzed within the holding specified in the April 9, 1991, QAPjP. The holding time specified is 10-day extraction and 40 days to analysis.
Calibration	All appropriate calibration criteria were met.
Blanks	No Aroclors were detected in the blanks.
Surrogates	HBB was used as the surrogate; however, this surrogate elutes in the PCB chromatographic pattern. Due to the presence of Aroclor 1260 in the samples, the results for the surrogates for most samples were either inflated due to the Aroclor concentrations or were diluted out in samples requiring 1/10, 1/100, or 1/1000 dilutions to quantify the Aroclor levels. The poor surrogate recovery should be noted with a qualifier stating they were either inflated due to Aroclor presence or were diluted out, but the surrogate recovery results should not impact the usability of the sample data.
Matrix Spikes/ Matrix Spike Duplicate Recoveries	Matrix spike and matrix spike duplicates were completed for samples RR15CO2. The results were outside the required precision and accuracy limits; however, the samples were not spiked with a sufficient level of Aroclor 1260 over the native level of the sample. In the case of sample RR16SD09, the native level is 206,226 ug/kg and the sample was only spiked with 142.857 and 143.430 ug/kg for MS and MSD, respectively. In the case of sample RR15CO2, the native level is 6538.84 ug/kg and the sample was only spiked with 98.8142 and 98.5221 ug/kg, respectively. The poor matrix spike recoveries should be noted in the final report, with a qualifier stating that the poor recovery levels resulted from adding an insufficient spike amount when compared to the native level in the sample. These poor recoveries should not impact the quality of the results for the non-spiked samples. The method standards (MSTD50052, MSTD50057, and MSTD50014) had recoveries of 102, 136, and 118 percent, respectively. This indicates that the laboratory adequately followed the method.
Field Duplicates	The results of the field duplicates RR15SD08DL and RR16SD08DDL are 44,000 and 46,000 ug/kg, respectively for Aroclor 1260. This is an RPD of 4.4 percent. There were no QC criteria specified for field duplicates.

Compound Identification and Quantification	Presence of the Aroclors were confirmed with a secondary column as specified in the analytical procedure. Data not confirmed with the secondary column were flagged with an "A" to indicate the potential presence of the Aroclor, but that its presence was not confirmed. Note that sample RR16SD12 is flagged with an "A" for Aroclor 1242. Therefore, the sample should be used with caution and should be flagged as "present but not confirmed with secondary column." However, the data value should represent a worst case.
Usability	All sample results for this batch are usable, however, data should be flagged as noted above.

Data Validation - Roosevelt Road
Control #4795
VLI No. 420.1, B #2, Set A

The following field numbers were included:

Field Number	Surrogate Recovery Outside Range (60-140%)
RR15SD01A	
RR15SD01B	
RR15SD02A	X
RR15SD02AMS	X
RR15SD02AMSD	X
RR15SD03A	X
RR15SD03B	
RR15SD04A	
RR15SD04B	
RR15SD05A	X
RR15SD06A	
RR15SD06DA	
RR15SD07A	X
RR15SD07B	X
RR15S01A	X
RR15S01B	X
RR15S02A	
RR15S03A	
RR15S04A	X
RR15S05A	X
RR15S05DA	X
RR15S06A	X
MSTD50270	X
PBLK03 (No data)	
PBLK04	

Holding Time — All samples were extracted and analyzed within the holding time specified in the April 9, 1991, QAPjP. Holding time is 10 days to extraction and 40 days to analysis.

Calibration — All appropriate calibration criteria were met.

Blanks — PBLK04 contained an estimated 69 ug/kg (J) of Aroclor 1260, however, this is below the detection limit of 100 ug/kg. Since value was below the detection limit, no corrective action was required to be taken. Data do not need to be adjusted or flagged; blank value on data report is reported as < 100 ug/kg.

Surrogates	HBB was used as the surrogate, however, this surrogate elutes in the PCB chromatographic pattern. Surrogate recoveries were within the ±40 percent accuracy range for 14 of 25 samples. For the remaining samples, the surrogate recoveries were inflated due to presence of one of the Aroclors. The poor surrogate recoveries in this case should be flagged with a data qualifier stating the results were inflated due to the presence of the Aroclors in the samples, but the surrogate recovery results should not impact the usability of the sample data.
Matrix Spike/ Matrix Spike Duplicate Recoveries	Matrix spike and matrix spike duplicate recoveries were 85 and 173 percent, respectively. Therefore, one value met the QC objectives of ±40 percent and one did not. The difference in the two values is probably due to the nonhomogenity of the sample matrix. The qualification of the data should be limited to the MS/MSD. The method standard had a recovery of 105 percent which indicates that the laboratory was able to adequately follow the method.
Field Duplicates	The results of the field duplicate, RR15SD06A and RR15SD06DA, were 1000 and 970 ug/kg for Aroclor 1260. These samples have an RPD of 3.0 percent. The results of the field duplicate, RR15SD05A and RR15SD05DA, were 2,500 and 1,700 ug/kg for Aroclor 1260. These samples have an RPD of 38.1 percent. No precision requirements were specified for field duplicates.
Compound Identification and Quantification	All samples were identified and quantified as specified in the method. All Aroclor results identified using the primary column were confirmed using the secondary column.
Usability	All sample results for this batch are usable, however, data should be flagged as note above.

Data Validation - Roosevelt Road
Control #4795
VLI No. 420.1, B #2, Set C

The following samples were included in B #2, Set C:

Field Number	Surrogate Outside Control Limit
RR15S24A	
RR15S24AMS	
RR15S24AMSD	X
RR15S24B	
RR15S25A	
RR15S25AD	
RR15S26A	
RR15S26AD	X
RR15S27A	
RR15S28A	
RR15S24AMSTD	
PBLK07	
PBLK08	

Holding Times — All samples were extracted and analyzed within the holding time specified in the April 9, 1991, QAPjP. Holding time specified is 10 days to extraction and 40 days to analysis.

Calibration — All appropriate calibration criteria were met.

Blanks — No Aroclors were detected in the blanks.

Surrogates — HBB was used as the surrogate, however, this surrogate elutes in the PCB chromatographic pattern. Due to the high concentration of Aroclor 1260 in sample RR15S26AD the surrogate recovery level was elevated and outside the QC objective limits of 60 to 140 percent. Sample RR15S24AMSD also had a surrogate recovery (145 percent) outside the QC range due to the presence of Aroclor 1260, however, this sample is a matrix spike duplicate and the recoveries of the sample and matrix spike of 138 and 140 percent, which are within the QC criteria. Therefore, the surrogate recoveries outside the QC range should be flagged for the specific sample with a qualifier stating the results were inflated due to the presence of Aroclors in the samples, but the surrogate recovery results should not impact the usability of the sample data.

Surrogates	HBB was used as the surrogate; this surrogate elutes in the PCB chromatographic pattern. The presence of Aroclors in the sample had a matrix interference on the HBB peak and quantification of the surrogate was difficult. Therefore, the surrogate results outside the specified QC range of 60 to 140 percent should be flagged. However, although there are interferences present that make quantification of the surrogate difficult, there should be no impact on the usability of the data.
Matrix Spike/ Matrix Spike Duplicate Recoveries	The MS/MSD recovery for RR15S06A was zero percent. The poor recovery was due to the addition of an insufficient quantity of the spike in comparison with the native concentration level (less than 50 percent of native level). Nonhomogenity of the sample may also contribute to the poor recovery. The poor spike recovery should be noted in the report with a data qualifier stating the reason for the poor recovery is due to an insufficient spike amount added to the sample and may also be a result of nonhomogenity of the native level. The method standard (MSTD50890) had a recovery of 66 percent, which is at the low end of specified QC recovery range of 60 to 140 percent. However, since it is in the acceptable range, it does appear that the laboratory was able to adequately complete the analytical procedures.
Compound Identification/ Qualification	Presence of the Aroclors were confirmed with a secondary column as specified in the analytical procedure. The Aroclor 1260 result for sample RR15S21A is flagged with an "X" indicating that the sample result was outside the standard calibration range. A review of the calibration data and the sample data indicate that the sample results may be low, therefore, it represents a conservative estimate of the Aroclor 1260 present in the sample. The data should be flagged qualifying the data.
Usability	All sample results for this batch are usable, however, the data should be flagged as noted above. The Aroclor 1260 result for Sample RR15S21A should be used as a conservative estimate of Aroclor 1260.

Data Validation - Roosevelt Road
Control #4774
VLI No. 420.1, B #1, Set A

The following samples were included in B #1, Set A:

Field Number	Surrogate Outside Control Limit
RR15W01	
RR15W02	X (ND)
RR15W03	X (ND)
RR15GB01	
RR16W01	
RR16W02	
RR16W03	
RR16W04	
RR16W05	
RR16W06	X
RR16W07	X
RR16W08	
RR16W09	
RR16W10	
RR16W11	
RR16W12	
RR16W13	
RR16W14	
RR16W15	
RR16W16	
RB0379	
MSTD50011	X

Holding Time — All samples were extracted and analyzed within the holding time specified in the April 9, 1991, QAPjP. Holding time is 10 days to extraction and 40 days to analysis.

Calibration — All appropriate calibration criteria were met prior to analysis of sample extracts. Sample analysis continued after outlying results for Aroclors 1242 and 1254 were obtained since these Aroclors were not tentatively identified in any of the samples analyzed after the calibration was determined to be out of specification. If either of these Aroclors had been detected, the samples would have been reanalyzed. Aroclor 1254 was detected in one sample; however, that sample was analyzed shortly after the initial calibration for the batch was completed and was not affected by the standard that did not meet the calibration criteria.

Matrix Spike/ Matrix Spike Duplicate Recoveries	The MS/MSD recoveries for RR15S24AMS and RR15S24AMSD were 96 and 90 percent and the RPD was 6 percent. Therefore, the results are in the specified QC limits of 60 to 140 percent for accuracy as measured by the recovery and 40 percent for precision as measured by the RPD. In addition, the method standard had a recovery of 96 percent, therefore, indicating that the laboratory adequately followed the method.
Compound Identification/ Quantification	All sample results from primary column analysis indicating the presence of Aroclors was confirmed with the secondary column.
Usability	All sample results for this batch are usable, however, data should be flagged as noted above.
Field Duplicates	There are no QC criteria established to evaluate the field duplicates. The field duplicates RR15S25A and RR15S25AD had results for Aroclor 1260 of 290 and 200 ug/kg, respectively. The RPD for the sample was 36.7 percent. The field duplicate results for RR15S26A and RR15S26AD for Aroclor 1260 were 1,500 and 59,000 ug/kg, respectively. The RPD for the sample was 190.1 percent.

Data Validation - Roosevelt Road
Control #4795
VLI No. 420.1, B #2, Set B

The following samples were included in B #2, Set B:

Field Number	Surrogate Outside Control Limit
PBLK05	* (low)
RR15S06DA	
RR15S06DAMS	* (low)
RR15S06DAMSD	* (low)
RR15S07A	
RR15S08ADL	* (low)
RR15S09A	* (low)
RR15S010A	* (low)
RR15S011ADL	* (low)
RR15S012A	* (low)
RR15S013A	* (low)
RR15S013B	
RR15S014ADL	* (low)
RR15S015A	
RR15S016A	
RR15S017A	
RR15S018A	
RR15S019A	
RR15S019B	
RR15S020ADL	* (low)
RR15S021ADL	* (low)
RR15S022ADL	
RR15S023A	
MSTD50290	* (low)

Holding Time — All samples were extracted and analyzed within the holding time specified in the April 9, 1991, QAPjP. Holding time is 10 days to extraction and 40 days to analysis.

Calibration — All appropriate calibration criteria were met.

Blanks — No Aroclors were detected in the blank.

Blanks	No Aroclors were detected in the blanks.
Surrogate	HBB was used as a surrogate; this surrogate elutes in the PCB chromatographic pattern. The presence of Aroclors in the sample had a matrix interference effect on the HBB peak and quantification of the surrogate was either inflated or could not be made in which case it was reported as ND. The poor surrogate recoveries should be noted for the specific samples with a data qualifier indicating that recoveries outside the QC limit were obtained, however, these poor recoveries should not impact the usability of the sample data.
Matrix Spike/ Matrix Spike Duplicate Recoveries	Matrix spike and matrix spike duplicates were not completed due to the matrix (wipes) of the samples. The recovery for the method standard was 136 percent which indicated that the laboratory adequately performed the method.
Field Duplicates	No field duplicates were completed.
Compound Identification/ Quantification	Presence of the Aroclors were confirmed with secondary column as specified in the analytical procedure. The Aroclor data for Sample RR15W03 is flagged with an "X" indicating that Aroclor 1254 and 1260 were detected and the results may be inflated due to the contribution of PCBs in the mixture. The data should be qualified and probably represents a worst case scenario. The results for Aroclor 1260 for Sample RR16W03 is flagged with a "Y." This indicates that the results were reported from the confirmation analysis rather than the quantitation analysis, since there were method intereferences for the quantitation result. For Sample RR16W10, the Aroclor 1260 result is flagged with an "A" which indicates that there was evidence to suggest the presence of the Aroclor in the quantitation analysis, however, the result was not confirmed in the secondary analysis. The data should be flagged and can be used to represent a worst case scenario. For Sample RR16W12, the Aroclor 1260 result is flagged with a "Z," which indicates that the result is an estimate reported below the detection limit. The results is 1.9 ug/m^2 and the detection limit is 2.0 ug/m^2. The data should be flagged indicating this.
Usability	All sample results for this batch are usable, however, data should be flagged as noted above.

Versar INC.

CHAIN OF CUSTODY RECORD

2 of 5

PROJECT NO.	PROJECT NAME	PARAMETERS	INDUSTRIAL HYGIENE SAMPLE
5295.3	NAVSTA Roosevelt Roads		Y

SAMPLERS: (Signature) Juliana de la Fuente (Printed) Juliana de la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	PCB								REMARKS
RR5501A	5/13/91	12:45	✓		Sib15-Soil-1	1	1								75703
RR5501B		12:30	✓		" - " - 1	1	1								75723
RR5502A		12:20	✓		" - " - 2	1	1								75704
RR5503A		12:45	✓		" - " - 3	1	1								75705
RR5504A		12:40	✓		" - " - 4	1	1								75706
RR5505A		12:30	✓		" - " - 5	1	1								75707
RR5505DA		12:35	✓		" - " - 5	1	1								75746
RR5506A		12:05	✓		" - " - 6	1	1								75708
RR5506DA		12:10	✓		" - " - 6	1	1								75744
RR5507A		12:00	✓		" - " —	1	1								75709
RR5508A		11:35	✓		" - " —	1	1								75710
RR5509A	✓	11:13	✓		" - " —	1	1								75710

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Juliana de la Fuente	5/14/91 10:00				
(Printed) Juliana de la Fuente		(Printed)	(Printed)		(Printed)

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				Use field sample #s on chain of custody reports; these samples labeled as such for cross-reference and verification only
(Printed)		(Printed)		

Distribution: Original Plus Copy Accompanies Shipment (white and yellow); Copy to Coordinator Files (pink)

HR-00206-03.13-03/15/92

Versar INC.

CHAIN OF CUSTODY RECORD

Soil B

PROJECT NO.	PROJECT NAME	PARAMETERS	INDUSTRIAL HYGIENE SAMPLE
5295.3	NAVSTA Roosevelt Roads		Y / N

SAMPLERS: (Signature) Juliangado la Fuente (Printed) Juliangado la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	PCB's								REMARKS
RR5 10A	5/13/92	11:15	✓		Site 15 - Soil - 10	1	1								75712
RR5 11A		11:20	✓		" - " - 11	1	1								75713
RR5 11B		11:25	✓		" - " - 11	1	1								75734
RR5 12A		10:20	✓		" - " - 12	1	1								75714
RR5 13A		10:35	✓		" - " - 13	1	1								75715
RR5 13B		10:30	✓		" - " - 13	1	1								75736
RR5 14A		10:40	✓		" - " - 14	1	1								75716
RR5 15A		10:00	✓		" - " - 15	1	1								75717
RR5 16A		10:55	✓		" - " - 16	1	1								75718
RR5 17A		10:50	✓		" - " - 17	1	1								75719
RR5 18A		10:35	✓		" - " - 18	1	1								75720
RR5 19A	✓	10:15	✓		" - " - 19	1	1								75721

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Distribution: Original Plus One Accompanies Shipment (white and yellow); Copy to Coordinator Field Files (pink).

RR 00206 03.13 05/15/92

4 of 5

Versar INC.

CHAIN OF CUSTODY RECORD

PROJECT NO.	PROJECT NAME
5295.3	NAVSTA Roosevelt Roads

SAMPLERS: (Signature) [illegible] (Printed) Juliano de la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	PARAMETERS: PCBs	INDUSTRIAL HYGIENE SAMPLE (Y / N)	REMARKS
RRISSMB	5/13/91	10:10	✓		Sib15-Soil-19	1	1		75701
RRISS20A		10:20	✓		" - " -20	1	1		75702
RRISS21A		13:07	✓		" - " -21	1	1		75750
RRISS22A		13:13	✓		" - " -22	1	1		75751
RRISS23A		13:31	✓		" - " -23	1	1		75756
RRISS24A		13:35	✓		" - " -24	1	1		75757
RRISS24B		13:35	✓		" - " -24	1	1		75758
RRISS25A		13:40	✓		" - " -25	1	1		75759
RRISS25AD		13:45	✓		" - " -25	1	1		75760
RRISS26A		13:50	✓		" - " -26	1	1		75761
RRISS26AD		13:55	✓		" - " -26	1	1		75762
RRISS27A	✓	14:00	✓		" - " -27	1	1		75763

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
[illegible]	5/14/91 11:00				
(Printed) Juliano de la Fuente		(Printed)	(Printed)		(Printed)

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RR-00206-03.13-05/15/92

Versar INC.

CHAIN OF CUSTODY RECORD

PROJECT NO.	PROJECT NAME	PARAMETERS	INDUSTRIAL HYGIENE SAMPLE
5295.3	NAVSTA Roosevelt Roads		Y / N

SAMPLERS: *(Signature)* [signature] (Printed) Juliana de la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS									REMARKS
							PB								
RR15SD01A	5/13/94	12:59	✓		Site 15 - Sed - 1	1	1								75687
RR15SD01B		12:59	✓		" - " - 1	1	1								75696
RR15SD02A		13:01	✓		" - " - 2	1	1								75690
RR15SD03A		11:10	✓		" - " - 3	1	1								75691
RR15SD03B		11:05	✓		" - " - 3	1	1								75697
RR15SD04A		9:55	✓		" - " - 4	1	1								75692
RR15SD04B		9:50	✓		" - " - 4	1	1								75698
RR15SD05A		12:20	✓		" - " - 5	1	1								75693
RR15SD06A		11:45	✓		" - " - 6	1	1								75694
RR15SD06DA		11:52	✓		" - " - 6	1	1								75702
RR15SD07A		10:05	✓		" - " - 7	1	1								75695
RR15SD07B	✓	10:00	✓		" - " - 7	1	1								75701

Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*
[signature]	5/14/94 10:00				
(Printed) Juliana de la Fuente		(Printed)	(Printed)		(Printed)

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				Use field sample #'s on analytical reports; three part label #'s are for cross-reference and verification only.
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RR-00206-03 13-05/15/92

Versar INC.

CHAIN OF CUSTODY RECORD

PROJECT NO.	PROJECT NAME	PARAMETERS	INDUSTRIAL HYGIENE SAMPLE
5275.3	NAVSTA Roosevelt Roads		Y / N

SAMPLERS: (Signature) [illegible] (Printed) Tulio de la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	PCBs								REMARKS
RR15 528A	5/13/91	1400	✓		[illegible]	1	1								75764

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
[illegible]	5/14/91 15:00				
(Printed) Tulio de la Fuente		(Printed)	(Printed)		(Printed)

Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks
				Keep filed sample #5 on the chain of custody report; three part label #5 will for cross-reference and inspection only.
(Printed)		(Printed)		

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RR-00208-03.13-05/15/92

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CHAIN OF CUSTODY RECORD

1 of 5

PROJECT NO.	PROJECT NAME	PARAMETERS	INDUSTRIAL HYGIENE SAMPLE
61-5295.3.1	NAVSTA Roosevelt Roads		Y / N

SAMPLERS: (Signature) [illegible]

(Printed) Julio de la Fuente

FIELD SAMPLE NUMBER	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS									REMARKS
							RB								
RR15W01	5/8	10:25		✓	Site 15 - Wipe - 1	1	1								75601
RR15W02	5/8	10:32		✓	" - wipe - 2	1	1								75602
RR15W03	5/8	10:35		✓	" " - 3	1	1								75605
RR15C02	5/8	10:40		✓	" - Chip - 2	1	1								75646
RR15C01	5/8	10:52		✓	" - Chip - 1	1	1								75640
RR15GB01	5/8	11:00		✓	Site 15	1	1								75647

None to follow for Site 15

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
[illegible]	[illegible]				
(Printed) [illegible]		(Printed)	(Printed)		(Printed)

Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks
(Printed)		(Printed)		use Field Sample nos. on analytical reports; these part label nos are for cross-reference and verification only

Distribution: Original Plus One Accompanies Shipment (white and yellow); Copy to Coordinator Field Files (pink).

RR-00208-03.13-05/15/92

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APPENDIX B

Remedial Action Alternatives
Analyses for Substation 2
Site 15, v.s. Naval Station
Roosevelt Roads (ESE, 1988)

REMEDIAL ACTION ALTERNATIVES ANALYSIS FOR SUBSTATION 2, SITE 15 U.S. NAVAL STATION ROOSEVELT ROADS

CONFIRMATION STUDY TO DETERMINE POSSIBLE DISPERSION AND MIGRATION OF SPECIFIC CHEMICALS U.S. NAVAL STATION ROOSEVELT ROADS

Contract No. N62470-85-B-7972

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
Sacramento, California

FEBRUARY 1988

C-SAC/PR-SITE15/TOC.1
2/24/88

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1.0 BACKGROUND

This report presents the remedial action alternatives analysis for the polychlorinated biphenyl (PCB)-contaminated soil at Substation 2, Site 15 at Naval Station (NAVSTA) Roosevelt Roads, Puerto Rico. This analysis includes an evaluation of four remedial action alternatives. The alternatives analysis is based on the results of the Characterization sampling and analysis, and risk assessment. Several clean-up levels for the PCB-contaminated soil are addressed in the remedial action alternatives analysis. The clean-up criteria eventually used are those which have been established by the Environmental Protection Agency (EPA) in the Toxic Substance Control Act (TSCA) policy for the clean-up of spilled PCBs. This policy establishes requirements for the clean-up of spills resulting from the release of materials containing PCBs at concentrations of 50 parts per million (ppm) or more. The requirements in this policy are based upon the Agency's evaluation of the potential routes of exposure and potential risks associated with PCB spills, as well as the cost of clean-up of these spills.

The Characterization of Site 15 was performed as part of the Confirmation Study for NAVSTA Roosevelt Roads. The objective of this Study is to determine if specific toxic or hazardous materials have contaminated the environment at the Navy activities and may include consideration of various remedial alternatives. The Study is part of the Navy Assessment and Control of Installation Pollutants (NACIP) program designed to identify contamination of Navy lands resulting from past operations and to institute corrective measures, as needed.

The NACIP program consists of three distinct phases:

- o Initial Assessment Study (IAS)--record searches and personnel interviews to collect and evaluate all evidence supporting the existence of a contamination problem at an installation.
- o Confirmation Study--on-site investigations including physical and analytical monitoring to confirm or refute the existence of contamination, and if necessary recommending both interim and long-term corrective measures.
- o Corrective Measures--institution of needed interim and/or long-term remedial measures to control and mitigate contamination.

The IAS phase of the NACIP for NAVSTA Roosevelt Road was conducted in 1984. Results of the IAS for Substation 2, Site 15, showed that sufficient evidence existed to indicate the potential presence of PCB contaminants in the soil that might pose an imminent health or environmental threat on or off the Naval facility. It has been estimated that 3,000 gallons of PCB-containing oil were discharged on the site from 1964 to 1979. In this period, Site 15 was used by the Public Works Department-Power Distribution Shop for the repair of pole-mounted distribution electrical transformers. Oil was drained from the transformers to repair the inner cores and coils and was subsequently poured onto the ground. It is suspected that the drained oil contained PCBs because the transformers were serviced with PCB-based dielectric fluids.

Because of recommendations made during the IAS, Site 15 is being further investigated in the Confirmation Study of the

NACIP program. The Confirmation Study is performed in sequential efforts, termed Steps, which are defined below.

Step	Description
IA	Verification of existence of contamination.
IB	Characterization of extent and rate of migration of contaminants, geohydrological, geophysical, and other factors.
II	Evaluation of alternatives to achieve compliance, preparation of cost estimates, and project effectiveness of alternatives.
III	Preparation of site operation and draft Government project documentation with cost estimate(s) satisfactory for project funding requests.

Verification Step sampling and analysis for Site 15 was completed in May 1986. This sampling program consisted of the collection and analysis of soil samples for PCBs. Because of the PCB contamination detected in the soil during the Verification Step, the study proceeded to the Characterization Step (Step IB). The Characterization sampling and analysis of Site 15 was completed in January 1988, and the results were used in performing the remedial alternatives analysis for the site.

Section 2.0 of this report presents the results of Verification sampling which led to the Characterization Study of Site 15. The results of the Characterization Step sampling are presented in Section 3.0 and the risk assessment is detailed in Section 4.0. The remedial alternatives analysis is given in Section 5.0

2.0 VERIFICATION STEP RESULTS

During the Verification Step (Step IA) for the NAVSTA Roosevelt Roads Confirmation Study, 16 soil samples were collected at Site 15 and analyzed for PCBs. Eight samples were collected from the area surrounding Substation 2, and eight samples were collected from the storage area located directly southeast of Substation 2 across Valley Forge Road. Each of the samples was a composite of the soil in the 0- to 1-foot (ft) depth interval. The analytical data for these soil samples show that PCB contamination exists in the area surrounding Substation 2; no PCB contamination was detected in the soil in the storage yard. The Verification Step sampling locations around Substation 2 are shown in Figure 2-1. The number by each sampling point is the PCB concentration for that location in ppm.

Based on results from the Verification Step sampling, Site 15 was recommended for additional soil sampling and analysis to delineate the extent of PCB contamination. This additional soil sampling and analysis was performed as the Characterization Step of the Confirmation Study.

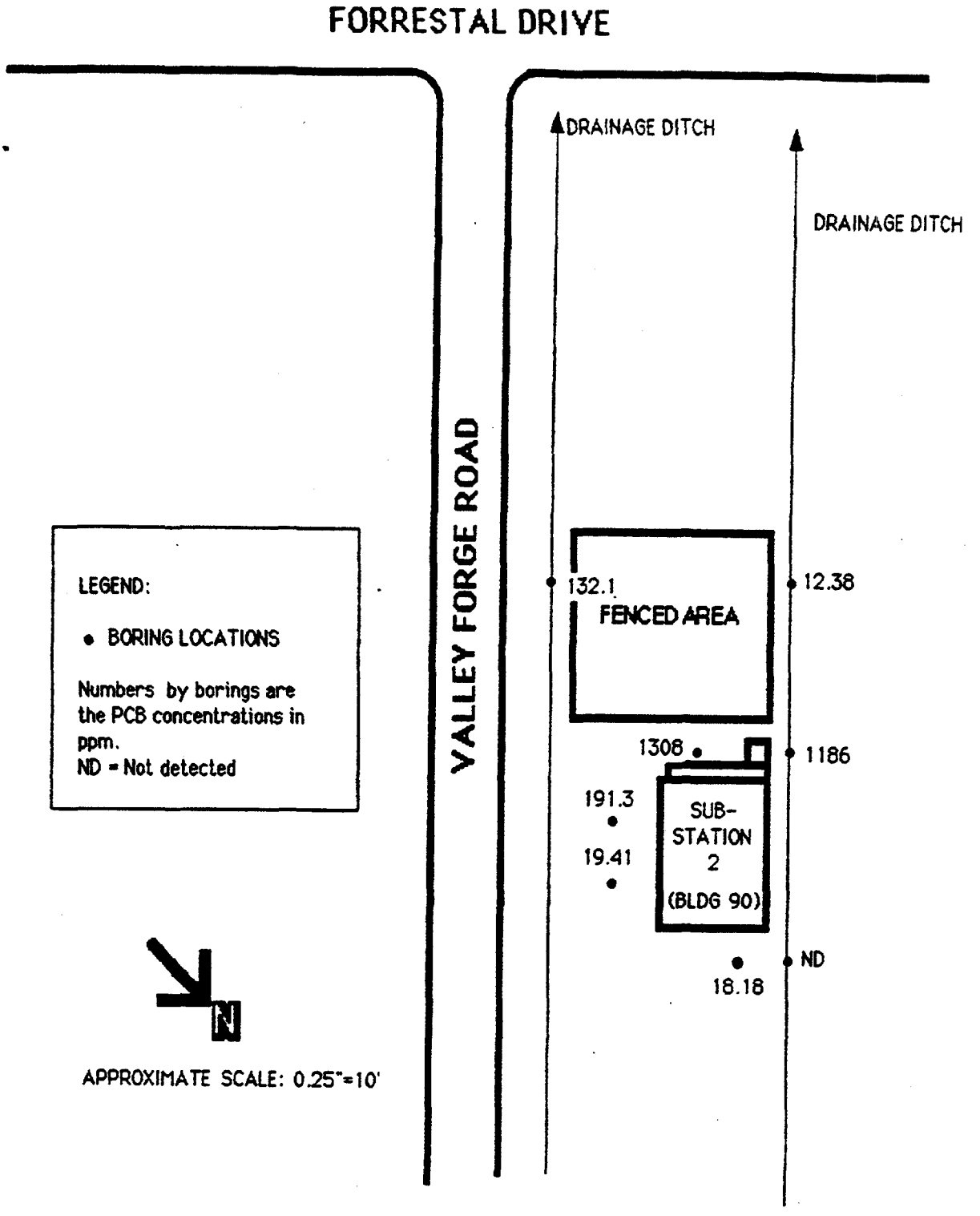

FIGURE 2-1
VERIFICATION SAMPLING LOCATIONS AND RESULTS AT SITE 15, SUBSTATION 2

CONFIRMATION STUDY
U.S. NAVAL COMPLEX
PUERTO RICO

3.0 CHARACTERIZATION STUDY

The work plan for the Characterization of Site 15 specified the drilling of 33 hand-augured soil borings. Borings were to be drilled to a depth of 3 ft with soil samples to be collected from the 0- to 1-ft depth, the 1- to 2-ft depth, and the 2- to 3-ft depth. The work plan specified that a total of 99 soil samples were to be collected for PCB analysis. However, during the field sampling coral was found generally at a depth of 9 to 12 inches which halted hand augering to greater depths. Consequently, only one soil sample was collected from all but two of the sampling locations. The two sampling locations where hand augering was performed to depths greater than 1 ft were located northeast of Substation 2 (Building 90).

A total of 36 soil samples were collected from the 33 sampling locations, 30 of which were collected from the 0- to 1-ft depth interval. All of the samples were extracted for PCB analysis, and the PCB analyses of the soils were performed in two batches. The first batch of samples consisted of those located in and nearest to the contaminant source area (area between Building 90 and the fenced area). The second batch of samples selected for PCB analyses was selected based on the results of the first batch. With this phased approach, a total of 15 samples were analyzed for PCBs.

The results of the Characterization sampling and analysis for Site 15 are presented in Figure 3-1. The numbers by the sampling points are the PCB concentrations in ppm for those locations. The numbers in parentheses are the PCB

concentrations detected in the preceding Verification Step of the study.

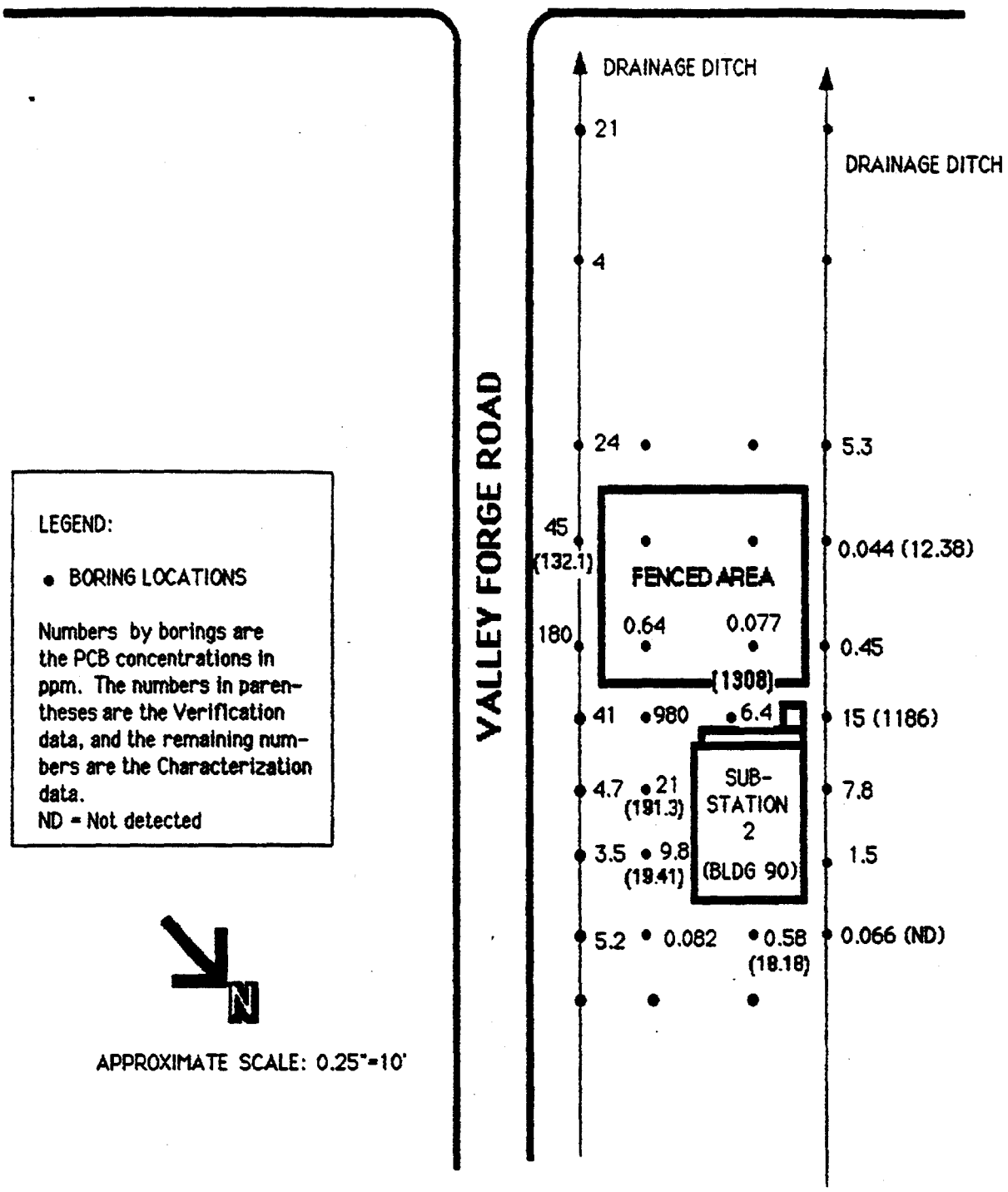

FIGURE 3-1
CHARACTERIZATION STEP SAMPLING LOCATIONS AND RESULTS AT SITE 15, SUBSTATION 2

CONFIRMATION STUDY
U.S. NAVAL COMPLEX
PUERTO RICO

4.0 RISK ASSESSMENT

The objective of this section is to determine whether the levels of PCBs in the soil at Site 15 pose a threat to human health and/or the environment. In this section a soil criterion will be developed that represents a safe level of residual PCB contamination. The development of the PCB soil criterion involved the evaluation of the PCB clean-up requirements set forth by EPA in the TSCA policy to determine their applicability to Site 15, and the performance of a site specific risk assessment. In the TSCA policy, EPA has established criteria to be used in determining the adequacy of the clean-up of spills resulting from the release of materials containing PCBs at concentrations of 50 ppm or greater occurring after May 4, 1987. This policy requires clean-up of PCB-contaminated soil to different levels depending upon the spill location, potential for exposure to residual PCBs remaining after clean-up, the concentration of the PCBs initially spilled, and the nature and size of the population potentially at risk of exposure. For PCB spill areas where there is a greater potential for human exposure to the PCB contamination, the policy requires more stringent clean-up standards. The TSCA PCB regulations are presented below by spill location description.

Spill Location Description	PCB Criterion
(1) Spills at outdoor electrical substations with restricted access	25-50 ppm

(2)	Spills at other restricted access locations other than electrical substations	25 ppm
(3)	Spills at nonrestricted access areas	10 ppm

Because the soil contamination at Site 15 exists in an open area with nonrestricted access to lawn maintenance and other station personnel, the 10 ppm clean-up standard would be applicable to the site.

To further evaluate the appropriateness of the 10 ppm clean-up standard for Site 15, a site specific risk assessment was performed. The objective of the risk assessment was the development of a safe level of residual PCB contamination (termed target concentration) based on site specific conditions.

The first step in determining target concentrations is the identification of actual and potential exposure pathways. Only complete exposure pathways are considered for the purpose of developing target concentrations. If any of these components is not present, then the exposure pathway is incomplete and would not be expected to contribute to the total exposure from the site.

A complete exposure pathway has four components:

1. A source of chemical release,
2. An environmental transport medium,

3. A point where human or environmental receptors could be exposed, and
4. A likely exposure route.

A screening of current and potential exposure pathways was conducted to determine which pathways are most significant for the site in terms of human exposure to contaminants. This screening step serves to eliminate from consideration those exposure scenarios in which contaminants may be released from the site but for which there is little or no potential for human contact. This screening also identifies those exposure pathways that are complete and will require detailed quantitative analysis to estimate the extent of human exposure. Environmental receptors were eliminated from further consideration because the contaminated area is too small to support significant populations.

The following routes of exposure have been identified for Site 15 based on the pathway screening analysis:

1. Exposure of workers or the public through dermal absorption of contaminated surface soil,
2. Exposure of workers or the public through incidental ingestion of contaminated surface soil,
3. Exposure of workers or the public through ingestion of contaminated drinking water, and
4. Exposure of workers or the public through inhalation of contaminated dusts and/or vapors.

The following paragraphs describe the rationale for selection or exclusion of the various exposure pathways for developing a target PCB concentration for Site 15.

Exposure Of Workers Or The Public Through Dermal Absorption Of Contaminated Surface Soil--The access to Site 15 by lawn maintenance crews and other station personnel could result in direct contact with soil on exposed skin surfaces and subsequent percutaneous absorption of contaminants. This exposure to soil through dermal absorption represents a complete pathway and, therefore, was included in subsequent analysis of a target PCB concentration.

Exposure Of Workers Or The Public Through Incidental Ingestion Of Contaminated Surface Soil--As a result of persons coming into direct contact with soil contaminants at Site 15, contaminated soil may be accidentally ingested. Persons who have been exposed to soil contaminants through direct contact may consume food items with soiled hands or otherwise ingest soil as a result of unintentional hand-to-mouth contact. Through these mechanisms, persons may actually ingest small quantities of contaminated soil from the site. Because this pathway is considered to be complete, it was included in the development of a target PCB concentration for the site.

Exposure Of Workers Or The Public Through Ingestion Of Contaminated Drinking Water--There are no drinking water wells on or near the site, and it is unlikely that significant leaching and migration of PCBs to the ground water, by infiltrating rainwater, is occurring because of the low solubility of PCBs in water. Because no exposure point has been identified and environmental transport is unlikely, this pathway is classified as incomplete and is eliminated from further consideration.

Exposure Of Workers Or The Public Through Inhalation Of Contaminated Dusts Or Vapors--Field investigations of Site 15 have indicated that some of the area is thinly vegetated. Consequently, dispersion of airborne PCB-contaminated dust during lawn mowing is a likely transport mechanism. However, migration via volatilization is an unlikely transport mechanism because PCBs are not very volatile and are not expected to volatilize from the soil. Therefore, dust inhalation, but not vapor inhalation, is considered a complete pathway and was included in development of a target PCB concentration for Site 15.

Based on this exposure pathways analysis, it appears likely that the worst case scenario involves dermal absorption, incidental ingestion, and dust inhalation of residual soil contaminants. Maximum conditions of exposure correspond to a worker performing ground maintenance 2 hours per day for 26 days out of the year. These assumptions were used to modify the dermal adsorption factor of 38 milligrams per day (mg/day) developed by Hawley (1985) to yield an annualized average dermal human intake factor of 0.226 milligrams (mg) of soil per day using the following equation:

$$38 \text{ mg/day} \times \frac{26 \text{ workdays/year}}{365 \text{ days/year}} \times \frac{2 \text{ hours/workday}}{24 \text{ hours/day}} = 0.226 \text{ mg/day}$$

The same level of activity was used to modify the lifetime average soil ingestion rate of 100 mg/day and the average inhalation rate for doing moderately heavy work of 2.8 cubic meters per hour (m^3/hour), both suggested by EPA (1986a). This yields an annualized average incidental soil ingestion

human intake factor of 0.594 mg/day and an annualized average inhalation exposure factor of 0.0166 m^3/day.

According to EPA policy, a total carcinogenic risk level of 10^{-6} is an acceptable risk for exposure of an individual to a hazardous waste site. The EPA approach (1986a) is to apportion an equal level of risk to each potential carcinogen at the site. But, because PCBs are the only observed carcinogen at the site, the PCB target risk level is the same as the total carcinogen risk level.

The target PCB oral chronic daily intake (CDI) at the site was then determined by dividing the target risk level of 10^{-6} by the oral route cancer potency factor of 4.34 $(mg/kg/day)^{-1}$ yielding a value of 2.30×10^{-7} mg/kg/day [kg = kilograms].

The target PCB inhalation CDI was calculated in a similar manner. However, because an inhalation route cancer potency factor for PCBs was not available in the technical literature, an assumed inhalation factor was used. In general, the inhalation factor is about an order of magnitude less than the oral route cancer potency factor, which is 4.34 $(mg/kg/day)^{-1}$ for PCBs. Threfore, an inhalation factor of 0.4 $(mg/kg/day)^{-1}$ was used to yield a target PCB inhalation CDI of 0.25×10^{-5} mg/kg/day.

Using Pathway Preliminary Pollutant Limit Values (PPLV) methodology, significant source-to-receptor pathway is quantified and the effects combined to ensure that an exposed individual will not receive an unacceptably large dose. Intermediate results of the method are referred to as single-pathway preliminary pollutant limit values (SPPPLVs) and

represent residual levels of contamination that would be safe if only that single pathway were operating. Several pathways are combined by the following equation:

$$PPLV = \frac{1}{\frac{1}{SPPPLV,1} + \frac{1}{SPPPLV,2} + \ldots}$$

The dermal absorption exposure pathway is defined as:

$$SPPPLV_{(D)} = B_W/W_S \times CDI$$

where: B_W = body weight of an adult (70 kg)
W_S = annualized average dermal human intake factor (0.226 mg/day)
CDI = 2.30×10^{-7} mg/kg/day

$$SPPPLV_{(D)} = \frac{70\ kg}{2.26 \times 10^{-7}\ kg/day} \times 2.30 \times 10\text{-}7\ mg/kg/day$$

$$= 71.2\ mg/kg$$

The incidental soil ingestion exposure pathway is defined as:

$$SPPPLV_{(I)} = B_W/W_{Si} \times CDI$$

where: B_W = body weight of an adult (70 kg)
W_{Si} = annualized average incidental soil ingestion human intake factor (0.594 mg/day)
CDI = 2.30×10^{-7} mg/kg/day

$$SPPPLV_{(I)} = \frac{70\ kg}{5.94 \times 10^{-7}\ kg/day} \times 2.30 \times 10-7\ mg/kg/day$$

$$= 27.1\ mg/kg$$

The dust inhalation exposure pathway is defined as:

$$SPPPLV_{(R)} = \frac{B_W \times CDI}{RB \times C_{SS}}$$

where:
- B_W = body weight of an adult (70 kg)
- RB = annualized average inhalation exposure factor (0.0166 m^3/day)
- C_{SS} = concentration of suspended particles in the air (assume 4×10^{-1} mg/m^3)
- CDI = 0.25×10^{-5} mg/kg/day

$$SPPPLV_{(R)} = \frac{70\ kg \times 0.25 \times 10-5\ mg/kg/day}{0.0166\ m^3/day \times 4 \times 10^{-1}\ mg/m^3}$$

$$= 0.0264\ kg/kg \text{ or } 2.64 \times 10^4\ mg/kg$$

The soil PCB PPLV criterion, i.e., the target residual PCB soil concentration, was developed assuming an average, representative scenario, where the same worker is exposed to contaminated soils through each of the 3 exposure routes. This PPLV is defined as follows:

$$PPLV = \frac{1}{\frac{1}{SPPPLV_{(D)}} \quad \frac{1}{SPPPLV_{(I)}} \quad \frac{1}{SPPPLV_{(R)}}}$$

The calculated PPLV for PCBs is 20 mg/kg. Therefore, based on the site specific risk assessment, the calculated PCB clean-up level is 20 mg/kg or ppm. However, the more conservative TSCA clean-up standard of 10 ppm will be used to provide an added degree of protection to human health in the clean-up of Site 15. This clean-up standard, along with the identified contaminant routes of exposure form the basis for development of the remedial action alternatives.

5.0 ALTERNATIVES ANALYSIS

The four remedial alternatives developed for Site 15 are described below and illustrated in Figures 5-1 through 5-4, respectively. These alternatives were developed based on the contaminant routes of exposure and clean-up level identified in the previous section. The four alternatives vary in the degree to which they address the PCB contamination problem at the site. For example, Alternative 1 applies the least stringent requirements for clean-up while Alternative 4 applies the most stringent.

Alternative 1 is the "no action" alternative. In this alternative a 6-foot (ft) high, galvanized chain link fence is to be installed around the site. The fence is to encompass all areas of the site confirmed to have PCB concentrations above 10 ppm. The fence is to be 542 linear feet (L.F.) long, enclosing a total area of 688 square yards (S.Y.).

In Alternative 2 a single-layered asphalt cap is to be installed over the site. This cap is to consist of 4 inches of base material and 1 inch of bituminous paving. The cap is to cover areas of the site confirmed to have PCB concentrations above 10 ppm. The cap is to have an area of 688 S.Y.

Alternative 3 specifies both partial excavation and capping. In this alternative site areas confirmed to have PCB concentrations above 25 ppm are to be excavated. A total of 96 cubic yards (C.Y.) of PCB-contaminated soil are to be removed by excavating an area of 288 S.Y. to a depth of 1 ft. The excavated areas are then to be backfilled with clean soil,

which is defined by EPA as containing less than 1 ppm PCBs. Futhermore, site areas confirmed to have PCB concentrations between 10 and 25 ppm are to be capped with a single-layered asphalt cap. This cap is to cover an area totaling 400 S.Y. The cap is to meet the same specifications as those specified in Alternative 2. Excavated material is to be disposed of by incineration in an incinerator permitted for PCB incineration.

Alternative 4 is the most stringent in meeting PCB clean-up criteria. In this alternative site areas confirmed to have PCB concentrations exceeding 10 ppm are to be excavated. A total of 229 C.Y. of PCB-contaminated soil are to be removed by excavating an area of 688 S.Y. to a depth of 1 ft. The excavated area is then to be backfilled with clean soil. Excavated material is to be disposed of by incineration.

Table 5-1 presents the estimated costs to implement each of the four remedial action alternatives, and Appendix A contains the detailed cost estimates for each alternative. Most of the cost estimates for these alternatives were performed using Mean Site Work Cost Data 1987. The exceptions are the hauling and disposal costs for the PCB-contaminated soil. These figures were obtained from ENSCO, the firm that operates the PCB-permitted incinerator nearest to Site 15, which is located in El Dorado, Arkansas. Hauling costs include freight charges from Site 15 to this location in Arkansas.

As shown in Table 5-1, the lowest cost alternatives are Alternative 1, which involves the construction of a fence around the area with a PCB concentration exceeding 10 ppm, and Alternative 2, capping. The costs for Alternatives 3 and 4 are significantly higher than those for Alternatives 1 and 2

because of the high costs associated with hauling and incineration of the contaminated soil.

The disadvantage of Alternatives 1 and 2 is that although the fencing/capping eliminates the human exposure pathways, these alternatives do not accomplish any reduction in toxicity or volume of the contamination. Likewise, Alternative 3, which provides treatment and destruction of a portion of the contaminated soil, only provides partial reduction of waste volume. The highest cost alternative, Alternative 4, provides treatment and destruction of all of the contaminated soil with a PCB concentration exceeding 10 ppm.

C-SAC/PR-SITE15/5.4
2/24/88

TABLE 5-1 SUMMARY OF COST ESTIMATES FOR REMEDIAL ACTION ALTERNATIVES FOR SITE 15, SUBSTATION 2

Alternative	Capital Cost ($)	Annual O&M Cost ($/YR)	Total Cost ($)*
1	$8,400	$50	$8,800
2	$2,900	$50	$3,300
3	$242,300	$50	$242,700
4	$574,000	0	$574,000

* Total Cost = Sum of capital cost and present worth of annual O&M cost assuming a period of 20 years at 10 percent interest rate.

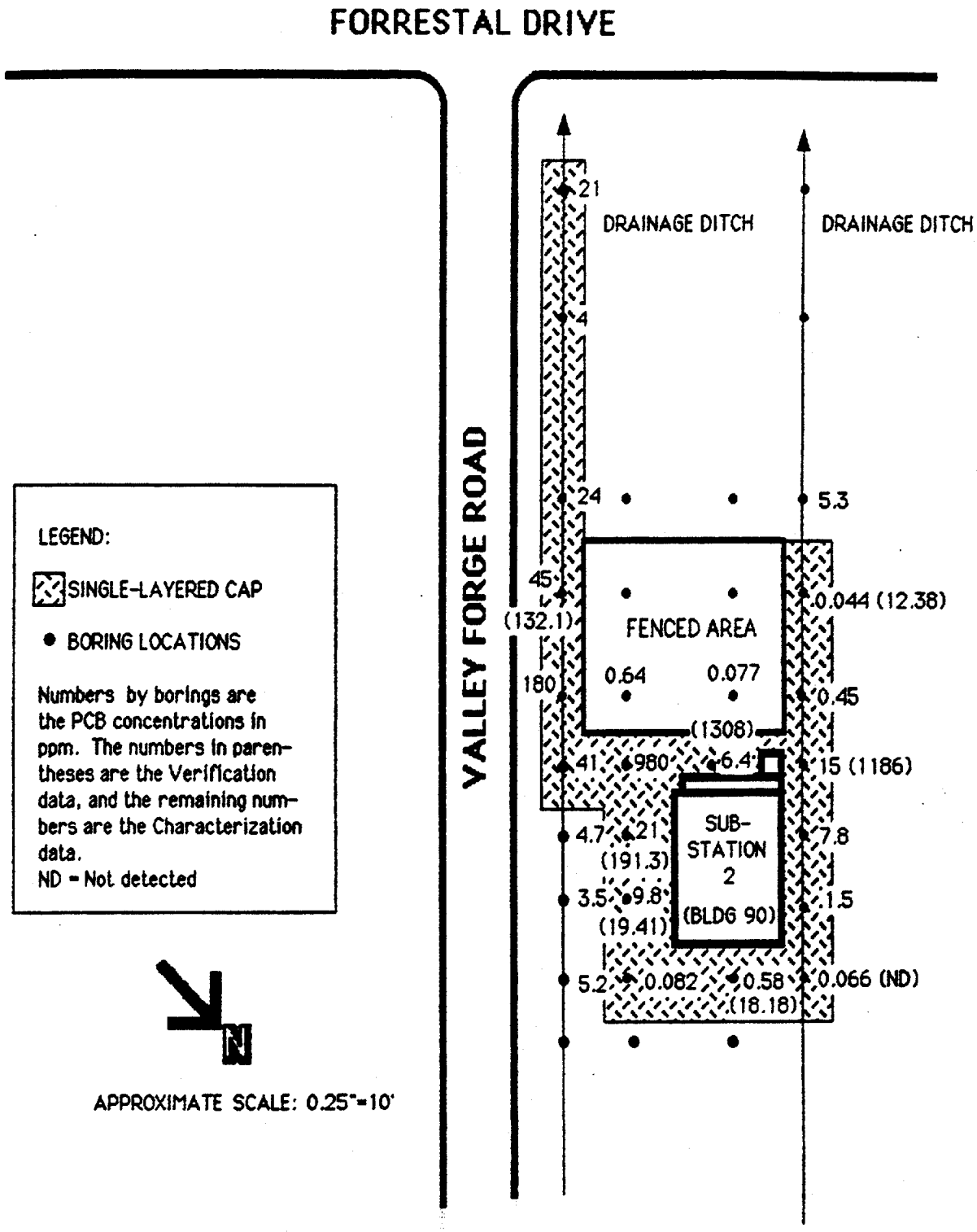

FIGURE 5-2
ALTERNATIVE 2, CAPPING,
SITE 15, SUBSTATION 2

CONFIRMATION STUDY
U.S. NAVAL COMPLEX
PUERTO RICO

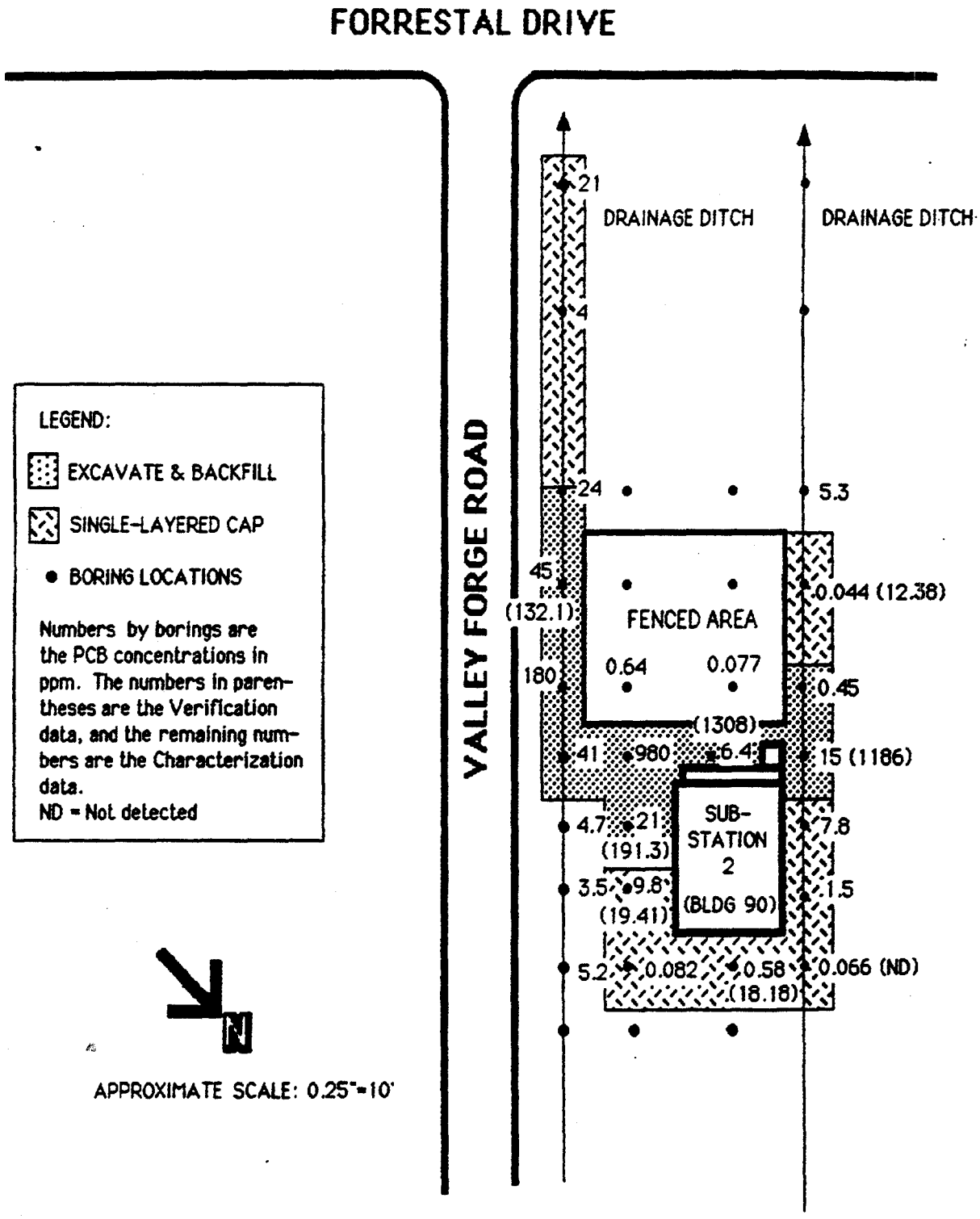

FIGURE 5-3
ALTERNATIVE 3, PARTIAL EXCAVATION AND CAPPING, SITE 15, SUBSTATION 2

CONFIRMATION STUDY
U.S. NAVAL COMPLEX
PUERTO RICO

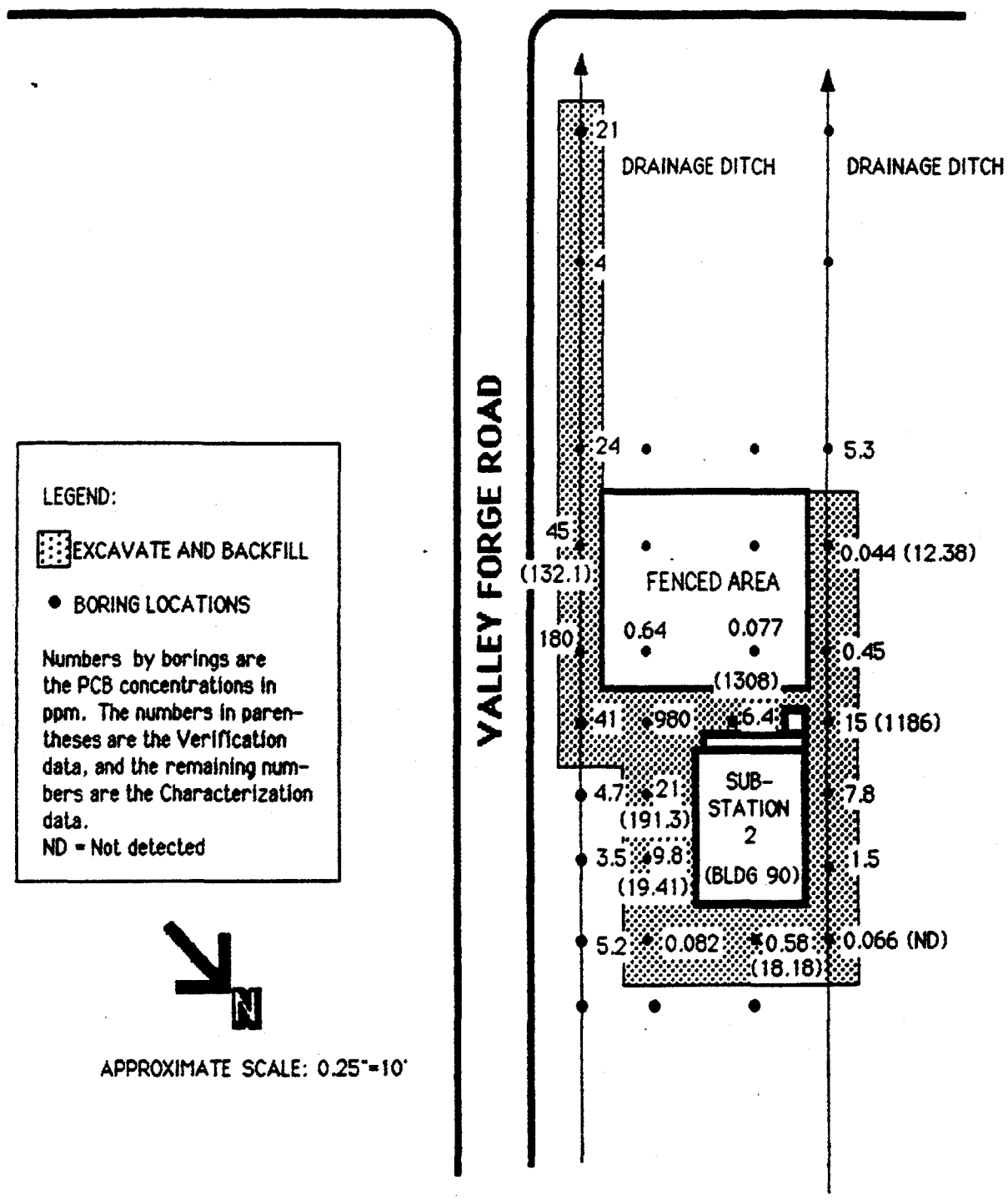

FIGURE 5-4
ALTERNATIVE 4, EXCAVATION,
SITE 15, SUBSTATION 2

CONFIRMATION STUDY
U.S. NAVAL COMPLEX
PUERTO RICO

6.0 REFERENCES

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APPENDIX A
COST ESTIMATES FOR REMEDIAL ACTION ALTERNATIVES

C-SAC/PR-SITE 15/A.2
02/25/88

ALTERNATIVE 1 NO ACTION

CAPITAL COST

FENCE, CHAIN LINK INDUSTRIAL 6' HIGH PLUS 3 STRANDS BARBED WIRE, 2" LINE POST @ 10' O.C. 1 - 5/8" TOP RAIL

6 GA WIRE, GALV. STEEL		
542 L.F. X $11.90/L.F.	=	$6,450
CORNER POSTS, 3" DIA GALV. STEEL		
7 POSTS X $66 EA	=	$462
BRACES, GALV. STEEL		
14 BRACES X $23 EA	=	$322
GATE		
1 X $90		$90
SUBTOTAL		$7,324
CONTINGENCY (15%)		$1,099
TOTAL CAPITAL COST		$8,423

ANNUAL O&M COST

ASSUME $50/YR

C-SAC/PR-SITE 15/A.3
02/25/88

ALTERNATIVE 2 CAPPING

CAPITAL COST

BITUMINOUS CAP, 1" THICK PAVING, 4" GRAVEL BASE

BORROW	76 CY X $7.30/CY	=	$555
COMPACTION	76 CY X $3.24/CY	=	$246
BITUMINOUS CAP	688 SY X $2.55/SY	=	$1,754
SUBTOTAL			2,555
CONTINGENCY (15%)			383
TOTAL CAPITAL COST			$2,938

ANNUAL O&M COST

ASSUME $50/YR

C-SAC/PR-SITE 15/A.4
02/25/88

ALTERNATIVE 3 PARTIAL EXCAVATION & CAPPING

CAPITAL COST

EXCAVATION & BACKFILL

EXCAVATION	96 CY X $2.83/CY	=	$272
BORROW	96 TONS X $1.98/TON	=	$190
HAUL BACKFILL	96 CY X $6.95/TON	=	$667
BACKFILL & COMPACTION	96 CY X $2.82/CY	=	$271
REVEGETATION	288 SY X $3.24/SY	=	$933

HAULING & INCINERATION

CONTAINERIZATION	96 CY X $251.46/CY	=	$24,140
FREIGHT SOIL	96 CY X $237.50/CY	=	$22,800
INCINERATION SOIL	96 CY X $1666.25/CY	=	$159,960

CAP

BORROW	44 CY X $7.30/CY	=	$321
COMPACTION	44 CY X $3.24/CY	=	$143
CAP	400 SY X $2.55/SY	=	1,020
SUBTOTAL			$210,717
CONTINGENCY			$31,608
TOTAL CAPITAL COST			$242,325

ANNUAL O&M COST

ASSUME $50/YR

C-SAC/PR-SITE 15/A.5
02/25/88

ALTERNATIVE 4 EXCAVATION

CAPITAL COST

EXCAVATION & BACKFILL

EXCAVATION	229 CY X $2.83/CY	=	$648
BORROW	229 TONS X $1.98/TON	=	$453
HAUL BACKFILL	229 CY X $6.95/TON	=	$1,592
BACKFILL & COMPACTION	229 CY X $2.82/CY	=	$646
REVEGETATION	688 SY X $3.24/SY	=	$2,229

HAULING & INCINERATION

CONTAINERIZATION	229 CY X $251.46/CY	=	$57,584
FREIGHT	229 CY X $237.50/CY	=	$54,388
INCINERATION	229 CY X $1666.25/CY	=	$381,571
SUBTOTAL			$499,111
CONTINGENCY (15%)			$74,867
TOTAL CAPITAL COST			$573,978

ANNUAL O&M COST = 0

Versar INC.

APPENDIX C

NAVSTA Roosevelt Roads
Stratigraphy

Versar INC.

GEOLOGIC FORMATIONS AT NAVAL STATION ROOSEVELT ROADS

BEACH DEPOSITS OF PEBBLES AND COBBLES (HOLOCENE)

- Moderately sorted, generally well-rounded local pebble and cobble deposits. Composed mainly of volcanic rock fragments from lavas and dikes, coral fragments, and calcareous sand. Gradational into sandy beach deposits. Thickness ranges from two to four meters or more.

LAGOON DEPOSITS (HOLOCENE)

- Mud and calcareous sand deposits periodically inundated by very shallow marine waters. Gradational into swamp deposits. Found on western side of Ensenada Honda. Thickness uncertain.

SWAMP DEPOSITS (HOLOCENE)

- Black to dark brown organic-rich soil and muck in poorly drained part of alluvial plains. In large part covered with mangroves. Thickness probably as much as five meters locally.

BEACH DEPOSITS (HOLOCENE AND PLEISTOCENE)

- Unconsolidated fine-to coarse-grained sand and pebble deposits. South of Ensenada Honda these desposits are composed of quartz and feldspar grains and plutonic and volcanic rock fragments, with considerable amounts of shell, algal, and coral fragments locally. From Ensenada Honda northward, quartz grains are rare and plutonic rock fragments uncommon; deposits are principally of calcium carbonate grains with local admixtures of volcanic rock fragments and pebble clasts. Gradational into, and partly overlain by, alluvial and swamp deposits. Thickness is probably more than 20 meters locally.

ALLUVIUM AND FANGLOMERATE (HOLOCENE AND PLEISTOCENE)

- Unconsolidated to poorly consolidated, poorly to well-sorted, clay to boulder-sized material in fans and in stratified alluvial valley fill deposits. Locally terraced; includes slope wash, small landslides, and channel fill deposits. Gradational into units mapped as predominantly alluvium, alluvial plain, and terraced deposits. Thickness locally more than 25 meters.

QUARTZ DIORITE AND GRAND DIORITE (TERTIARY AND UPPER CRETACEOUS)

- Light gray to light olive gray stocks of medium- to fine-grained unfoliated rock with hypodiomorphic-granular texture. Composition ranges from quartz diorite

to grandodiorite. Hornblende is the predominant mafic mineral; only minor amounts of biotite are present. Rounded metavolcanic xenoliths are locally present. A sample from the stock at the head of the Rio Daguao exhibits a peculiar fine-grained allotrimorphic-granular quarts and feldspar groundmass for the otherwise normally developed medium-grained minerals in the quartz diorite.

QUARTZ KEROTOPHYRE (TERTIARY AND UPPER CRETACEOUS)

- Stocks of medium-dark-gray to medium-bluish-gray porphyritic rock with an aphanitic matrix in north-central part of mapped area. Contains oliogoclasse and bipyramidal quartz phenocrysts. Weathers to grayish yellow, dusky yellow, and light brown. The quartz phenocrysts and the light colors are distinctive, interior parts of the intrusive are massive in aspect, although the rock is commonly much jointed and locally shattered. Borders of the intrusive are often irregular, with numerous apophyses and dikes extending into the county rock. Groundmass is an intricate intergrowth of quartz albite and oligoclase. X-ray diffraction indicates that somewhat more than 10% of the rock is potassium feldspar, but this could not be confirmed optically. Phenocrysts of plagioiclase are albite and aligoclase in crystals about one to four millimeters in length. The three-millimeter-long quartz phenocrysts appear to be resorbed and rounded, although a bipyramidal shape is plainly evident in many of them. Epidote is common as patches and stringers throughout the rock.

FIGUERA LAVA (LOWER CRETACEOUS)

- Andesitic lava sequence with intercalations of volcaniclastic breccia and tuft. Exposures generally confined to artificial cuts; most slopes show only float of lava fragments in soil. Medium-dark-gray to dark-gray, reddish-brown weathering lavas are generally fine-grained, medium-bedded to massive, and locally autobrecciated. The lava contains small, scattered andesine phenocrysts and sparese pyroxene pheoncrysts. Quart is fairly common in inlets, stringers, and blebs ranging from three to nine centimeters in length. The original composition of the groundmass appears to have been largely andesine and clinopyroxene with minor magnetite, but in most places the groundmass is altered to epidote, chlorite, tremolite-actinolite, quartz, and clay. Local amygdaloidal lavas have quartz, epidote, and calcite as vesice fillings. Some lenticular zones of pillow lava are scattered through the section; the pillows range from one to two meters in diameter, and generally a light-colored, aphanitic, silicified material occupies the interstices between the pillows. One thin, light gray tuft bed crossed by Highway 975 along the ridge crest west of Ceiba appears in thin section to contain devitrified pumice fragments and glass shards in a brown cryptocrystalline groundmass containing scattered broken plagioclase and pyroxene crystals. A planar texture is readily discernible in the rock, and it is interpreted as a nonwelded andesitic ash flow tuft, relatively rich in crystal fragments. Volcaniclastic rocks occur in units a few meters thick as interbeds within the main lava sequence. These rocks include some graded tufts

in layers two to eight centimeters thick, but are mainly medium- to thick-bedded coarse tuft to lapilli tuft and tuft breccia. Clasts include some cherty-looking material that may be a silicified tuft as well as minor pumaceous fragments, but are generally fine-grained lava and amygdaloidal lava, like that of the main part of the figuera. An especially thick massive breccia underlying pillow lavas can be found along route 972 on the ridge in the northwest part of the Naquabo quadrangle. The breccia is made up of angular to rounded pebble-sized clasts of pumice, amygdaloidal fine-grained lavas, and locally, silicified tuft in calcareous clinopyroxene-bearing tuft matrix. As much as 2,000 meters of Figuera Lava may be exposed in the area.

MIXED ZONE (LOWER CRETACEOUS)

- Interstratified Figuera Lava and Daguao Formation.

DAQUAO FORMATION (LOWER CRETACEOUS)

- Interbedded volcanic breccia, lava, and subordinate volcanic sandstone and crystal tuft. The volcanic breccia is medium gray, massive, and is composed of clasts of dark-gray irregularly shaped subangular to subrounded granule-to cobble-size porphyritic andesite lava in a medium gray coarse-grained plagioclase and clinopyroxene crystal tuft matrix. The breccia units are commonly cut by fine-grained and prophyritic lava dikes. Breccia beds are generally exposed only in artificial excavations, and float on natural slopes consists largely of lava clasts. Lavas are principally medium-dark gray andesites with a pilo-taxitic texture and andesine and clinopyroxene phenocrysts; they are locally amygdaloidal. Some of these lavas are flow breccias, with porphyritic andesite clasts commonly more than five centimeters in diameter, either welded together or in a matrix of speared andesite. Some dark-greenish-gray, very fine-grained flows are also autobrecciated. Typical massive tuft breccia can be seen in housing excavations just northwest of Daquao; good breccia and lava exposures can be found along the coast southeast of Hucares. Coarse autoclastic lavas may be found throughout the section in the ridge directly west of Ensenada Honda and Langley Drive, on the Roosevelt Roads Naval Reservation. Dark- to medium-gray volcanic sandstones and tufts are usually laminated to thin-bedded and graded, and are locally crossbedded. A few crystals tufts are hornblende-rich; most sand stones and tufts are composed of plagioclase and clinopyroxene grains like the matrix of the massive volcanic breccias, and calcareous are fairly common. The sandstones and tufts generally form units only a few meters thick in the western part of the mapped area. Notably thicker sequences in the east are shown by diagonal lines. Thick sequences of thin-bedded to laminated tuft are well exposed along the coast from Punta Algodones to Punta Cascajo, on the roosevelt roads Naval Reservation. Rocks of the Daguao Formation are commonly epidotized and chloritized in varying degrees. Volcaniclastic hornfels occurs in a few places near the diorite and granodiorite stocks, and small exposures of phyllitic to schistone rocks (s) occur in one area

north of Daquao, south of the keratophyre stocks. The formation interfingers with the overlying Figuera Lava in a few places; its base is not exposed. The thickness of the Daguao is estimated to be on the order of 1,000 to 1,500 meters.

DAGUAO INTRUSIVE BRECCIA (LOWER CRETACEOUS)

- Hypabyssal intrusive rock medium-dark-gray brecciated andesite. Contains subangular clasts of dark-gray andesite with large plagioclase and clinopyroxene phenocrysts in a brecciated matrix of the same composition. The clasts seem to be lithologically identical to andesite clasts in the tuft breccias and autoclastic lavas of the Daguao Formation. The clasts of the two intrusive bodies in the Naguabo quadrangle east of Daguao range from three to 15 centimeters in length; on Isla Pineros in the Punta Puerca quadrange blocks as large as 90 centimeters in length are found in an intrusive body making up a small hill on the northwest corner of the island. The intrusive rocks are locally much epidotized and silicified; the epidote and quartz occur in veins and in irregular patches. In a quarry in the intrusive body that is south of the Roosevelt Roads airfield some podshaped zones several meters long have been largely replaced by epidote and quartz, yet the original texture of the porphyritic andesite breccia is discernible. An exposure of massive andesite lava about 100 meters wide and 200 meters long on the crest of the ridge to the northwest of Naquabo may also be an intrusive body. The lave is lithogically similar to the other intrusive breccias; although it is only partly brecciated, it does show some near vertical banding (flow lines).

Versar INC.

APPENDIX D

IRIS Listing (U.S. EPA, 1991)

1 - HSDB
NAME - POLYCHLORINATED BIPHENYLS
RN - 1336-36-3
RELT - 6352 [AROCLOR 1016]
RELT - 6353 [AROCLOR 1221]
RELT - 6354 [AROCLOR 1232]
RELT - 6355 [AROCLOR 1242]
RELT - 6356 [AROCLOR 1248]
RELT - 6357 [AROCLOR 1254]
RELT - 1822 [AROCLOR 1260]
RELT - 3946 [2,4,5,2',4',5'-HEXACHLOROBIPHENYL]
RELT - 3947 [2,4,5,3',4',5'-HEXACHLOROBIPHENYL]
RELT - 3948 [3,4,5,3',4',5'-HEXACHLOROBIPHENYL]
RELT - 3949 [3,4,3',4'-TETRACHLOROBIPHENYL]
SY - Chlorinated diphenyl **PEER REVIEWED**
SY - PCB **PEER REVIEWED**
SY - 1,1'-Biphenyl, chloro derivs **PEER REVIEWED**
SY - Caswell no 672A **PEER REVIEWED**
SY - EPA pesticide chemical code 017801 **PEER REVIEWED**
SY - Clophen **PEER REVIEWED**
SY - Kanechlor **PEER REVIEWED**
SY - Aroclor **PEER REVIEWED**
SY - Fenclor **PEER REVIEWED**
SY - Chlorextol **PEER REVIEWED**
SY - Inerteen **PEER REVIEWED**
SY - Monter **PEER REVIEWED**
SY - Phenoclor **PEER REVIEWED**
SY - Pyralene **PEER REVIEWED**
SY - Pyranol **PEER REVIEWED**
SY - Santotherm **PEER REVIEWED**
SY - Sovol **PEER REVIEWED**
SY - Therminol **PEER REVIEWED**
SY - Noflamol **PEER REVIEWED**
SY - Biphenyl, polychloro- **PEER REVIEWED**
SY - Chlorinated biphenyl **PEER REVIEWED**
SY - Chlorinated diphenylene **PEER REVIEWED**
SY - Chloro 1,1-biphenyl- **PEER REVIEWED**
SY - Dykanol **PEER REVIEWED**
SY - Montar **PEER REVIEWED**
SY - Santotherm fr **PEER REVIEWED**
SY - Therminol fr-1 **PEER REVIEWED**
SY - Chloro biphenyl **PEER REVIEWED**
SY - Polychlorobiphenyl **PEER REVIEWED**
MF - ND
ASCH - Aroclor;12767-79-2
MMFG - ... FROM DIPHENYL & NAPHTHALENE WHICH MAY BE REACTED TO VARYING DEGREES WITH CHLORINE TO PRODUCE A NUMBER OF CMPD DESIGNATED BY VARIOUS TRADE NAMES SUCH AS AROCLOR. ... [HAMILTON. INDUS TOX 3RD ED 1974 , p. 289] **PEER REVIEWED**
MMFG - Chlorinated anilines are coupled with chlorinated benzenes by using an excess of the latter reactant which also serves as the solvent medium. The coupling reaction proceeds smoothly after the addition of isoamyl

nitrate, and the PCB product is readily isolated after a series of chromatographic procedures. [Mullin MD et al; Environ Sci Technol 18 (6): 468-76 (1984)] **PEER REVIEWED**

MMFG - PCBS ARE PREPD INDUSTRIALLY BY THE CHLORINATION OF BIPHENYL WITH ANHYDROUS CHLORINE IN THE PRESENCE OF A CATALYST SUCH AS IRON FILINGS OR FERRIC CHLORIDE. THE PRODUCTS ARE COMPLEX MIXT OF CHLOROBIPHENYLS, WHOSE DEGREE OF CHLORINATION DEPENDS PRINCIPALLY ON THE TIME OF CONTACT (12-36 HR) OF THE BIPHENYL WITH ANHYDROUS CHLORINE. [IARC MONOGRAPHS. 1972-PRESENT V18 54 (1978)] **PEER REVIEWED**

FORM - Aroclor mixtures which General Electric used in transformers have contained anywhere from 13% to 60% trichlorobenzene, with the remainder being pentachlorobiphenyl or hexachlorobiphenyl or mixtures of either tri-, penta-, or hexachlorobiphenyl and tetrachlorobenzene. [USEPA; PCDDs and PCDFs From PCBs Transformer and Capacitor Fires p.23 (1984) USEPA 600/2-85/036] **PEER REVIEWED**

FORM - In the USA, Aroclor is the most familiar requested trademark, but PCBs have also been marketed as Chloretol, Dyknol, Inerteem, Noflamol, and Pyranol. In other countries, PCB formulations have been sold as Pyralene (France), Phenoclor (France), Kanechlor (Japan), Santotherm (Japan), Fenclor (Italy), Apirolio (Italy), Soval (USSR), Delor (Czechoslovakia) and Clophen (West Germany). [US Dept of Interior/Fish & Wildlife Service Contaminant Reviews; Polychlorinated Biphenyls Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review Biol Rept No (85) 1.7 p.5 (1986)] **PEER REVIEWED**

FORM - There are 209 isomers/congeners of which 5 to 10 generally contribute more than 10% to the polychlorinated biphenyl content of Aroclor, Clophen, Phenochlor, and Kanechlor. [USEPA; Drinking Water Quality Criteria Doc: Polychlorinated Biphenyls (PCBs) ECAO-CIN-414 p.II-1-7 (1987)] **PEER REVIEWED**

MFS - Monsanto, the sole domestic manufacturer of PCB's /manufactured/ this chemical in its Sauget, IL plant. [Durfee RL; p.103-107 in Conference Proceedings: National Conference on Polychlorinated Biphenyls (1976) USEPA 560/2-75/004] **PEER REVIEWED**

OMIN - Commercial production /of PCB's/ was initiated in the United States in 1929 in response to the electrical industry's need for an improved dielectric insulating fluid (nonconductor of direct current) for use in transformers and capacitors which would also provide increased fire resistant benefits. [KIRK-OTHMER. ENCYC CHEM TECH 3RD ED 1978-PRESENT V5 844] **PEER REVIEWED**

OMIN - Domestic /USA/ production of polychlorinated biphenyls was stopped in October 1977. [KIRK-OTHMER. ENCYC CHEM TECH 3RD ED 1978-PRESENT V5 844] **PEER REVIEWED**

OMIN - All Aroclor products are characterized by a four digit number. The first two digits represent the type of molecule; 12= chlorinated biphenyl, 54= chlorinated terphenyl. Aroclor 25-- and 44-- are blends of PCB and chlorinated terphenyls (75% and 60% PCB, respectively). The last two digits give the weight percent of chlorine. Aroclor 1016 contains 41% chlorine per weight but the penta-, hexa-, heptachlorobiphenyl content is significantly reduced. [Hutzinger O et al; The Chemistry of PCBs p.7 (1974)] **PEER REVIEWED**

USE - EPA AUTHORIZED THE USE OF POLYCHLORINATED BIPHENYLS IN A NON-TOTALLY ENCLOSED MANNER IN HYDRAULIC SYSTEMS, HEAT TRANSFER SYSTEMS, IN

MICROSCOPY AS MOUNTING MEDIUM, & IN SMALL QUANTITIES FOR RESEARCH & DEVELOPMENT UNTIL JULY 1, 1984 (EPA IS PROPOSING TO AMEND THE RULE GOVERNING USE OF PCBS AS MOUNTING MEDIUM & IN RESEARCH & DEVELOPMENT). [48 FR 52402 (1983)] **PEER REVIEWED**

USE - /Used/ in electrical capacitors, electrical transformers, vacuum pumps, & gas-transmission turbines. [MERCK INDEX. 10TH ED 1983 , p. 1091] **PEER REVIEWED**

USE - PCBS /SRP: AS AROCLORS/ ARE WIDELY USED AS ENZYME INDUCERS IN RESEARCH LABORATORIES THROUGHOUT THE WORLD. THERE ARE INDICATIONS THAT CHLORINE CONTENT OF PCB MIXTURES IS RELATED TO LEVEL OF INCR ENZYMATIC ACTIVITY: MIXTURES CONTAINING LOWER PERCENTAGE OF CHLORINES WERE LESS ACTIVE THAN THOSE CONTAINING A HIGHER PERCENTAGE. [IARC MONOGRAPHS. 1972-PRESENT V18 74 (1978)] **PEER REVIEWED**

USE - The fire-resistant nature of the polychlorinated biphenyls ... combined with outstanding thermal stability made them excellent choices as hydraulic and heat transfer fluids alone or in formulations. They were also used to improve the waterproofing characteristics of surface coatings and have been used in the manufacture of carbonless copy paper, printing inks, plasticizers, special adhesives, lubricating additives, and vacuum pump fluids. [KIRK-OTHMER ENCYC CHEM TECH 3RD ED 1978-PRESENT V5 p.844] **PEER REVIEWED**

USE - Former uses of PCB's /as of 1974/ hydraulic fluids, plasticizer in synthetic resins, adhesives, plasticizer in rubbers, heat transfer systems, wax extenders, dedusting agents, pesticide extenders, inks, lubicants, cutting oils, carbonless reproducing paper. [Hutzinger O et al; The Chemistry of PCB's p.8 (1974)] **PEER REVIEWED**

CPAT - Capacitors, 70%; Transformers, 30% (1975) /Aroclors/ [Durfee RL et al; p.103-107 in Conference Proceedings: National Conference on Polychlorinated Biphenyls (1976) USEPA 560/2-75/004] **PEER REVIEWED**

PROD - ND

IMPT - Imports /of PCB's/ were terminated in 1980 in response to compliance with the Toxic Substances Control Act (TSCA) [Holton GA et al; Haz Waste & Haz Materials 2 (4): 453 (1985)] **PEER REVIEWED**

EXPT - (1986) ND [CITATION] **PEER REVIEWED**

COFO - Lower chlorinated Aroclors (1221, 1232, 1016, 1242, and 1248) are colorless mobile oils. Increasing chlorine content results in mixtures taking on the consistency of viscous liquids (Aroclor 1254) or sticky resins (Aroclors 1260 and 1262). Arclors 1268 and 1270 are white powders. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p. A-3 (1980) EPA 440/5-80-068] **PEER REVIEWED**

BP - ND

SOL - ND

VAP - ND

EVAP - ND

OCPP - Solubility in water is extrememly low; soluble in oils and organic solvents. [IARC MONOGRAPHS. 1972-PRESENT V18 49 (1978)] **PEER REVIEWED**

OCPP - With the exception of Aroclors 1221 and 1268, Aroclors do not crystallize upon heating or cooling, but at a specific temperature, defined as a "pour point", change into a resinous state. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.A-3 (1980) EPA 440/5-80-068] **PEER REVIEWED**

TOXS - ND

TXHR - Classification of carcinogenicity: 1) evidence in humans: limited; 2) evidence in animals: sufficient. Overall summary evaluation of carcinogenic risk to humans is Group 2A; the agent is probably carcinogenic to humans. /From table/ [IARC MONOGRAPHS. 1972-PRESENT S7 70 (1987)] **PEER REVIEWED**

HTOX - IN SURVEY OF 3 GROUPS OF WORKERS EXPOSED TO POLYCHLORINATED BIPHENYLS (PCBS) SERUM PCB CONCN WERE QUANTITATED AS LOWER PCB & HIGHER PCB. SERUM LOWER PCB & HIGHER PCB CONCN WERE MANY TIMES GREATER AMONG WORKERS EMPLOYED IN POWER CAPACITOR MANUFACTURING THAN AMONG GENERAL POPULATION. POSITIVE CORRELATIONS OF SYMPTOMS SUGGESTIVE OF MUCOUS MEMBRANE & SKIN IRRITATION, MALAISE & ALTERED SENSATION WERE NOTED WITH INCR CONCN OF SERUM PCB. NO CLINICAL ABNORMALITIES ATTRIBUTABLE TO EXPOSURE TO PCB WERE OBSERVED. SERUM CONCN WERE POSITIVELY CORRELATED WITH INCR OF GLUTAMIC-OXALACETIC TRANSAMINASE, SERUM GAMMA-GLUTAMYL TRANSPEPTIDASE & PLASMA TRIGLYCERIDE, & INVERSELY CORRELATED WITH PLASMA HIGH DENSITY LIPOPROTEIN-CHOLESTEROL. [SMITH AB ET AL; BR J IND MED 39 (4): 361-9 (1982)] **PEER REVIEWED**

HTOX - Deaths that occurred up to 5 1/2 yr after first exposure to PCB's ... were reported. Nine (41%) of 22 deaths were due to malignant neoplasms. Three of the tumors occurred in the stomach, one in the liver, two in the lung and one in the breast, and two were malignant lymphomas. (Kuratsune, 1976; Omae, 1975) [IARC MONOGRAPHS. 1972-PRESENT V18 82 (1978)] **PEER REVIEWED**

HTOX - A significant correlation was found between plasma levels of polychlorinated biphenyls(PCBs) in mothers occupationally exposed to these cmpd and the PCB milk levels. It has been observed that if these mothers nursed their babies for more than three months, the PCB levels in the infants exceeded that of their mothers. These cmpd were subsequently retained in the children for many years. ... [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1755] **PEER REVIEWED**

HTOX - /RESPONSES TO PCBS/: ACNE; HYPERPIGMENTATION OF SKIN; HYPERACTIVE MEIBOMIAN GLANDS; CONJUNCTIVITIS; EDEMA OF EYELIDS; SUBCUTANEOUS EDEMA; KERATIN CYSTS IN HAIR FOLLICLES; HYPERPLASIA OF HAIR FOLLICLE EPITHELIUM; HEPATIC HYPERTROPHY; DECR NUMBER OF RED BLOOD CELLS; DECR HEMOGLOBIN; SERUM HYPERLIPIDEMIA; LEUCOCYTOSIS. [IARC MONOGRAPHS. 1972-PRESENT V18 70 (1978)] **PEER REVIEWED**

HTOX - A leaking heat exchanger in a chemical plant discharged polychlorinated biphenyl (PCB) vapors. No employees worked routinely at the point of leakage. but breathing zone levels in work areas were found to be 0.1 mg/cu m. The period of exposure was 19 months. Seven of 14 exposed workers developed mild to moderate chloracne after exposure durations of 5-14 months. Liver function tests showed normal serum bilirubin, 24 and 48 hr cephalin flocculations, thymol turbidities, and serum alkaline phosphatase activities in six of the seven workers, but borderline increases in cephalin flocculation and thymol turbidity in the seventh. After 13 months, the thymol turbidity but not the cephalin flocculation had improved. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-56 (1980) EPA 440/5-80-068] **PEER REVIEWED**

HTOX - An analysis of the health effects of polychlorinated biphenyls (PCB) on eight laboratory workers involved in testing dielectric fluids was

made. ... The workers, all males 25 to 49 yr of age, had been employed 2.5 to 18 yrs. Breathing zone, point source, and general work area samples were collected on three separate occasions. The ranges were: breathing zone, 0.014 to 0.073 mg/cu m; point source (near an oven), 0.042 to 0.264 mg/cu m; and room area, 0.013 to 0.15 mg/cu m. Blood concns were 36 to 286 ppb which is substantially above the range in several studies of general populations. Workers complained of dry, sore throat (6/8), skin rash (3/8), gastrointestinal disturbances (3/8), and eye irritation and headache (2/8). Examination disclosed one patient with skin rash, two with nasal irritation, one showing rales, and four with high blood pressure, but no abnormalities in liver function. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-55 (1980) EPA 440/5-80-068] **PEER REVIEWED**

HTOX - Irregular menstrual cycles, early abortions and the birth of small, hyperpigmented and hyperkeratotic infants have been observed. [IARC MONOGRAPHS. 1972-PRESENT V18 37 (1978)] **PEER REVIEWED**

HTOX - Spirometric findings in a retrospective cohort of 136 capacitor workers with occupational exposure to polychlorinated biphenyls (PCBs) during active use (1976) and after the PCB ban (1979 and 1983) are reported. Quantitative exposure levels are not known. Subjects were categorized as having high, medium, or low exposure depending primarily on the extent of dermal contact. Mean 1979 serum PCB levels were elevated 35 to 40 times the normal level. Duration of employment ranged from 1-35 yr. Obstructive impairment was consistently found in 15% of the workers in 1976 and 1979. A history of respiratory illness and reduced FEV 1/FVC was correlated in a dose-response fashion with PCB exposure category and serum PCB levels in females in 1976 but the association disappeared in 1979. It is not clear whether the association held when controled for smoking. There was no association between PCB exposure and abnormal pulmonary function tests in males. [Lawton R et al; J Occup Med 28 (6): 453-6 (1986)] **PEER REVIEWED**

HTOX - PCBS ARE LIVER TOXINS & CAUSE CHLORACNE & POSSIBLY PERIPHERAL NEUROPATHY IN MAN. [NRC. DRINKING WATER & HEALTH 1977 , p. 757] **PEER REVIEWED**

HTOX - The first documentation of human effects as a result of ingestion of PCBs was derived from the Japanese poisoning incident that occurred in 1968. The victims suffered an acute toxicosis from consuming rice oil contaminated with an industrial oil, Kanechlor-400, consisting of a mixture of polychlorinated biphenyls (PCB), polychlorinated dibenzofurans (PCDF), and polychlorinated quinones (PCQ). The average total amount of PCBs consumed was estimated to be approximately 2 g, with approximately 0.5 g being the least total amount consumed by an affected group of some 325 people at the time. ... The most notable symptoms of Yusho among 189 patients included dark brown pigmentation of nails and skin, follicular accentuation, acneform eruptions, increased eye discharge, increased sweating at the palms and feeling of weakness. ... [Kuratsune M et al; Environ Health Perspect 1: 119-28 (1972) as cited in USEPA; Drinking Water Qual Crit Doc: Polychlorinated Biphenyls (PCBs) ECAO-CIN-414 p.VI-15 (1987)] **PEER REVIEWED**

HTOX - A mass outbreak of a peculiar skin disease /including pigmentation and acne from eruptions/ was recorded in Taichung and Changwa in Central Taiwan. The cause of the disease was later identified to be the

ingestion of rice bran oil contaminated with polychlorinated biphenyls (PCBs), and there were > 1900 victims. Blood PCB levels of 66 affected persons ranged from 11-720 ppb (mean 49 ppb) at approx 9-12 months after consumption of the PCB-contaminated oil. [Chen PH et al; Bull Environ Contam Toxicol 25: 325-9 (1980) as cited in USEPA; Drinking Water Qual Crit Doc: Polychlorinated Biphenyls (PCBs) ECAO-CIN-414 p. VI-14 (1987)] **PEER REVIEWED**

HTOX - Polychlorinated biphenyl blood residues were measured in 29 infertile males and in 14 matched control subjects at a hospital in Jerusalem, Israel. The patients' ages ranged from 25 to 45 years. The patients exhibited one or more impaired semen characteristics such as decreased spermatozoa count, lower sperm motility, or a greater proportion of morphologically abnormal spermatozoa. The control group, matched by age and smoking habits, consisted of randomly selected patients with minor illnesses. Each of them had at least one child not older than two years of age. None of the subjects had a history of occupational exposure to organochlorine compounds. The polychlorinated biphenyl levels were measured by GC-ECD. The mean concentration of total polychlorinated biphenyls in the infertile patients was 11.21 +/- 13.48 ng/g blood serum (range 0 to 64.2 ng/g). The control subjects had a mean concentration of 7.94 +/- 14.69 ng/g (range 0 to 47.3 ng/g). [Pines A et al; Arch Environ Contam Toxicol 16: 587-597 (1987)] **QC REVIEWED**

HTOX - A retrospective cohort mortality study of workers exposed to polychlorinated biphenyl (PCBs) in two plants manufacturing electrical capacitors was reported in 1981. The study was conducted primarily to examine the risk of cancer mortality associated with exposure to PCBs: due to the availability of animal data, liver cancer was the disease of most interest. Because of the small number of deaths and a relatively short observation period the study was inconclusive. Therefore, the study was updated by adding 7 yr of observation increasing the number of deaths in the study cohort from 163 to 295. Mortality from all causes was found to be lower than expected (295 observed versus 318 expected deaths) as well as mortality from all cancers (62 observed versus 80 expected deaths). A statistically significant excess in deaths was observed in the category that includes cancer of the liver (primary and unspecified), gall bladder, and biliary tract (5 observed versus 1.9 expected; $p < 0.05$). Most of this excess was observed in women employed in one plant. [Brown DP; Arch Environ Health 42 (6): 333-9 (1987)] **QC REVIEWED**

HTOX - The possibility of polychlorinated biphenyl-induced porphyria after transplacental exposure was investigated using children born to mothers exposed to contaminated rice oil in central Taiwan in 1979. The exposure was to a mixture of thermally degraded polychlorinated biphenyls, polychlorinated quaterphenyls, & polychlorinated dibenzofurans, which had become mixed with the oil during processing. Women who became pregnant had children with high perinatal mortality and a dysmorphic syndrome. Seventy four controls and 12 siblings of the exposed children were included in the study. Four of the transplacentally exposed children, 2 controls and 1 sib had a type B hepatic porphyria; total porphyrin excretion was elevated in the exposed children as a group (95 ug/l, exposed; 81 ug/l, control); and 8 of the 75 exposed children and 2 controls had total urinary porphyrin

concentrations of >200 ug/l. The children did not appear to have symptoms directly attributable to porphyria, but a mild disturbance in porphyrin metabolism appeared to be related to their intrauterine exposure. [Gladen BC et al; Arch Environ Health 43 (1): 54-8 (1988)] **QC REVIEWED**

HTOX - People occupationally exposed to PCB's have relatively high PCB residue levels. [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1753] **PEER REVIEWED**

HTOX - The Carcinogen Assessment Group (CAG), Office of Health and Environmental Assessment in EPA'S Research and Development Office, has prepared a list of chemical substances for which substantial or strong evidence exists showing that exposure to these chemicals, under certain conditions, causes cancer in humans, or can cause cancer in animal species which in turn, makes them potentially carcinogenic in humans. Substances are placed on the CAG list only if they have been demonstrated to induce malignant tumors in one or more animal species or to induce benign tumors that are generally recognized as early stages of malignancies, and/or if positive epidemiologic studies indicated they were carcinogenic. Polychlorinated biphenyls are on that list. [USEPA/CAG; The Carcinogen Assessment Group's List of Carcinogens (7/14/80)] **PEER REVIEWED**

HTOX - Digestive symptoms such as abdominal pain, anorexia, nausea, vomiting, jaundice, with rare cases of coma and death, may occur. At autopsy, acute yellow atrophy of the liver was found in lethal cases. ... Neurological symptoms such as headache, dizziness, depression, nervousness ... and other symptoms such as fatigue, loss of weight, loss of libido and muscle and joint pains were found in various percentages of exposed people. ... By the study of PCB-associated diseases in the general population, pathological pregnancies (toxemia of pregnancy, abortions, stillbirths, underweight births, etc) were frequently associated with increased PCB serum levels. ... [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1753] **PEER REVIEWED**

HTOX - Mother's milk contaminated with PCB's appears to be a source of exposure for infants. Developmental abnormalities have been observed in PCB-intoxicated infants. Premature eruption of teeth was observed ... and larger frontal and occipital fontanelles, exophthalmos and the maintenance of an abnormally wide sagittal suture were observed. ... [IARC MONOGRAPHS. 1972-PRESENT V18 82 (1978)] **PEER REVIEWED**

HTOX - Skin and mucous membrane changes; swelling of the eyelids, burning of the eye, and excessive eye discharge, burning sensation and edema of face and hands, simple erythematous eruptions with pruritus, acute eczematous contact dermatitis, chloracne, hyperpigmentation of skin and mucous membranes, discoloration of finger nails and thickening of the skin were reported. [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1754] **PEER REVIEWED**

HTOX - CATEGORIES OF KNOWN OR SUSPECTED ORG CHEM CARCINOGENS FOUND IN DRINKING WATER: HIGHEST OBSERVED CONCN IN FINISHED WATER: 3 UG/L; UPPER 95% CONFIDENCE ESTIMATE OF LIFETIME CANCER RISK: 3.1X10-6 UG/L. [NRC. DRINKING WATER & HEALTH 1977 , p. 794] **PEER REVIEWED**

HTOX - Dental records were studied and dental exams given to children living in Taiwan transplacentally exposed to polychlorinated biphenyls (PCB) (Yu-Cheng babies) as confirmed by epidemiological studies in the early

1980s. Nine school aged Yu-Cheng males and 9 females were compared to an unexposed reference group of 26 males and 18 females on the prevalence of missing permanent teeth germ while taking congenital factors into account. Among 9 transplacental Yu-Cheng girls, 4 were missing permanent teeth germ due to congenital factors. Among the 18 girls in the reference group, none were missing permanent teeth germ due to congenital factors. Among 9 transplacental Yu-Cheng boys, 1 was missing permanent teeth germ due to congenital factors. Among the 26 boys in the reference group, 1 was missing permanent teet germ due to congenital factors. [Lan SJ et al; Bull Environ Contam Toxicol 42 (6): 931-4 (1989)] **QC REVIEWED**

HTOX - A job exposure matrix was developed linking the work tasks in the Swedish National Census of population 1960 to exposure to 50 single agents or groups of substances, including polychlorinated biphenyls. All 1,905,660 men (ages 20-64 yr) in 1960, reporting themselves as gainfully employed in the Census, were observed for the occurrence of urothelial cancer during the 1961-1979 period by linkage to the National Swedish Cancer Registry. Only subjects in 1 work task, electricians in electric power stations, were assigned exposure to polychlorinated biphenyls with a moderate predictive value. The relative risk (with 95% confidence interval) for this group was 1.3 (1.0-1.8) for urinary bladder cancer. [Steineck G et al; Am J Ind Med 16 (2): 209-24 (1989)] **QC REVIEWED**

HTOX - In Taiwan in 1979, rice oil contaminated with polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans was ingested by approx 2000 people. Blood samples were taken from 36 women who were potentially exposed, and 24 non-exposed women (controls). The frequency of sister chromatid exchanges in lymphocytes from their heparinized whole blood was assessed after culturing cells in the presence or absence of 40 uM alpha-naphthoflavone for 72 hr. There was no significant difference in baseline sister chromatid exchanges for PCB exposed compared to the control group (7.29 vs 7.61). In contrast, addition of alpha-naphthoflavone resulted in a dramatic induction of sister chromatid exchange frequencies in PCB exposed lymphocytes ($p < 0.01$). PCB exposed frequencies increased to 10.75, while those of the unexposed group only increased to 8.85. [Thompson C et al; Chemosphere 18 (1-6): 687-94 (1989)] **QC REVIEWED**

NTOX - PCB ADMIN HAS BEEN FOUND TO RESULT IN INCREASED SYNTHESIS, HEPATIC CONTENT & EXCRETION OF PORPHYRINS IN RATS, QUAILS & CHICKENS; & THIS HAS BEEN ASSOCIATED WITH AN INCR IN LIVER MITOCHONDRIAL GAMMA-AMINOLEVULINIC ACID SYNTHETASE. [IARC MONOGRAPHS. 1972-PRESENT V18 74 (1978)] **PEER REVIEWED**

NTOX - The carcinogenicity of polychlorinated biphenyls was shown in animal, experimentally exposed. Benign and malignant liver cell tumors, lymphomas and leukemias, and carcinomas of the gastrointestinal tract were obtained. [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1754] **PEER REVIEWED**

NTOX - EXPOSURE OF RATS, RABBITS, MONKEYS, CHICKS AND RAINBOW TROUT TO PCBS RESULTED IN INCREASED ACTIVITY OF ... URIDINE DIPHOSPHOGLUCURONOSYLTRANSFERASE & NITROREDUCTASE, OR A SIGNIFICANT INCR IN THE LEVEL OF CYTOCHROME P450. [IARC MONOGRAPHS. 1972-PRESENT V18 74 (1978)] **PEER REVIEWED**

NTOX - EGGSHELL THINNING, LOSS OF REPRODUCTIVE ABILITY, OR BOTH HAVE BEEN ATTRIBUTED ... TO PCBS /IN BIRDS/. [HAYES. TOX OF PESTICIDES 1975 , p. 498] **PEER REVIEWED**

NTOX - ISOMERICALLY PURE PCBS WERE TESTED AS INDUCERS OF HEPATIC DRUG-METABOLIZING ENZYMES IN THE RAT. THE CHLORINATED BIPHENYL ISOMERS CAN BE CATEGORIZED INTO 2 DISTINCT GROUPS OF INDUCERS, WHILE COMMERCIAL PCB MIXT HAVE CHARACTERISTICS OF BOTH GROUPS. BIPHENYLS CHLORINATED SYMMETRICALLY IN BOTH THE META AND PARA POSITIONS INCREASE THE FORMATION OF CYTOCHROME P448, BUT DECREASE THE AMINOPYRINE N-DEMETHYLASE ACTIVITY. BIPHENYL ISOMERS CHLORINATED IN BOTH THE PARA AND ORTHO POSITIONS INDUCE THE FORMATION OF CYTOCHROME P450 AND N-DEMETHYLASE ACTIVITY. ISOMERS WHICH ARE CHLORINATED IN ONLY 1 RING, OR ARE CHLORINATED IN BOTH RINGS BUT NOT IN THE PARA POSITIONS, HAVE VERY LITTLE ACTIVITY AS INDUCERS OF LIVER ENZYMES. [GOLDSTEIN JA ET AL; CHEM-BIOL INTERACT VOL 17 (1): 69-87 (1977)] **PEER REVIEWED**

NTOX - The most consistent pathological changes occurring in mammals after polychlorinated biphenyls (PCB) exposure are in the liver. In rats, rabbits, and guinea pigs ... fatty deposits after acute injections and similar changes in rabbits and guinea pigs after dermal application /were observed/. In feeding experiments, marked fatty metamorphosis was noted in guinea pig liver with intracellular hyaline bodies observed in rats. Less striking changes were noted in the kidneys, lung, adrenals, and heart of guinea pigs. Rats exposed repeatedly to dietary PCBs showed increased liver weights. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-37 (1980) EPA 440/5-80-068] **PEER REVIEWED**

NTOX - Hepatic microsomal activity was elevated by single large doses of Aroclor 1242. Monkeys given 300 ppm for 90 days developed alopecia, chloracne, subcutaneous edema, liver hypertrophy, and hypertrophy and hyperplasia of the gastric mucosa. [GOSSELIN. CTCP 5TH ED. 1984 II-171] **PEER REVIEWED**

NTOX - Animal studies have shown that polychlorinated biphenyls (PCBs) can cross the placental barrier and are excreted in the mother's milk. [IARC MONOGRAPHS. 1972-PRESENT V18 37 (1978)] **PEER REVIEWED**

NTOX - GROUPS OF 10 MALE & 10 FEMALE 3-4-WEEK-OLD SHERMAN RATS WERE FED 0, 20, 100, 500 OR 1000 MG AROCLOR 1260/KG DIET ... SEVERAL ... GIVEN THE TWO HIGHEST DOSE LEVELS DIED BEFORE 6 MO. ... LESIONS ... DESCRIBED AS ADENOFIBROSIS OF LIVER OCCURRED IN 2 MALES FED 1000 MG/KG & IN 1, 1 AND 4 FEMALES FED 100, 500, AND 1000 MG/KG ... (KIMBROUGH ET AL, 1972) [IARC MONOGRAPHS. 1972-PRESENT V18 67 (1978)] **PEER REVIEWED**

NTOX - Certain substitution patterns are believed to influence the biological activities of chlorobiphenyls. The presence of two adjacent carbon atoms without chlorine substitution in one or both rings is believed to facilitate metabolism because it permits the formation of arene oxide intermediates. Essentially all chlorobiphenyls with five or fewer chlorine atoms have at least one pair of adjacent unsubstituted carbon atoms because of the rarity of 3,5-substitution in the natural mixtures. ... Chlorobiphenyls with three or four chlorine atoms in the ortho-positions (2- and 6-) are more easily metabolized by humans than those with only one or two ortho- chlorines. ... Chlorobiphenyl isomers with chlorine substitutions in both the 4- and 4'- positions tend to be biologically active and well retained in tissues. [USEPA; Ambient Water

Quality Criteria Doc: Polychlorinated Biphenyls p.A-9-11 (1980) EPA 440/5-80-068] **PEER REVIEWED**

NTOX - In addition to the inhibition of tumor induction by some chemicals, PCBs were also shown to inhibit the growth of experimental tumors in rats. Sprague-Dawley rats were innoculated with Walker 256 carcinosarcoma cells and the effects of PCBs determined. Both dietary and injected aroclor 1254 reduced the size of solid tumors and increased animal life span. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-75 (1980) EPA 440/5-80-068] **PEER REVIEWED**

NTOX - The time course of induction and inhibition of several enzymes in the liver of male C57BL/6 and ddy mice fed a diet containing Kanechlor-500 (500 ppm) was examined. Controls were maintained without treatment. Four animals/group were killed at 1, 2, 3, 6, and 10 weeks, following a 24 hr fast. In treated C57BL/6 and ddY mice there was an increase in the microsomal p450 level at 1 week. In treated C57BL/6 mice, the activity of mitochondrial delta-aminolevulinic acid synthetase (ALA-S) gradually increased for 2 wk (5.7 times the control value) and then rose rapidly for 3 wk (20 times the control value). These changes were accompanied by the rapid development of porphyria (characterized by increased excretion and hepatic accumulation of uroporphyrin). The activity of uroporphyrinogen decarboxylase (URO-D) was depressed approximately 40% within the first wk and 80% within 3 wk. In treated ddY mice there was a moderate increase of ALA-S (8 times the control at 3 wk); URO-D activity was unaffected for 3 wk and a significant decrease (p value not given) was observed at wk 6. Activities of ALA-S and URO-D in both strains of control mice were constant during the study. The control level (time 0) of URO-D in ddY mice was significantly higher ($p < 0.01$) than that of C57BL/6 mice, whereas control ALA-S activities were similar in the 2 strains. In C57BL/6 mice, the hepatic uroporphyrin level was elevated during the first week of exposure. By the third week, the liver porphyrin level was 2100 times that of the controls. Porphyrin did not accumulate in treated ddy mice at week 3, was slightly increased at week 6, and remained constant at week 10. There were no increases in uroporphyrin levels in untreated mice. /Kanechlor-500/ [Seki Y et al; Toxicol Appl Pharmacol 90 (1): 116-25 (1987)] **QC REVIEWED**

NTOX - Groups of eight female Sprague-Dawley rats were fed 50 ppm Aroclor 1242 or Aroclor 1254 in their normal diets for seven months. One group of animals served as controls. Because (86)Rb mimics K+ in membrane transport, it was used to assess the amount of K+ uptake in erythroid cells. In a culture medium depleted of K+, the uptake of (86)Rb by erythroid cells was significantly lower in the Aroclor 1254-treated group (7.78%) ($p < 0.05$) compared with the control group (21.9%). Uptake of (86)Rb in the Aroclor 1242-treated group was not significantly lower than that of controls. In a sodium-depleted culture medium, erythroid cells from only the Aroclor 1254-treated animals showed a minimal, but significant reduction in (86)Rb uptake (1.16%) ($p < 0.05$) compared with the control group (3.91%). The difference in 86(Rb) uptake between the Na+ and K+-depleted culture media was attributed to the relative saturation of the K+ transport system. When erythroi cells were challenged with ouabain in order to suppress Na+, K+, and ATPase

activity, (86)Rb uptake was depressed in all but the Aroclor 1254 group (this group had already been maximally depressed). [Byrne JJ, Sepkovic DW; Arch Environ Contam Toxicol 16: 573-7 (1987)] **QC REVIEWED**

NTOX - Juvenile rainbow trout (Salmo gairdneri) were fed diets of coho salmon containing polychlorinated biphenyls (PCBs) naturally bioaccumulated from Lake Michigan, Lake Ontario, or the Pacific Ocean for a 20 wk period. Gas chromatographic analysis indicated that the bioaccumulated PCB levels in rainbow trout were similar to the levels in coho salmon used as dietary supplements. Following dietary exposure to control chow or coho salmon from the Pacific Ocean, the rainbow trout contained low PCB levels, whereas trout which were fed Lake Michigan salmon and Lake Ontario salmon contained logarithmically elevated levels of PCBs. The effect on natural resistance was assessed by challenge with a titrated dose of Vibrio anguillarum (VA-58). The ability to mount a protective immune response in trout exposed for a 20-wk period to control or Lake Ontario coho salmon diets was determined by immunization with a VA-58 bacteria followed by challenge with virulent VA-58. A high level of protective immunity was demonstrated in all dietary groups suggesting that the parameters of host resistance of rainbow trout were not compromised following dietary exposure to Great Lakes coho salmon. [Cleland GB et al; Aquatic Toxicol 13 (4): 281-290 (1989)] **QC REVIEWED**

NTOX - Eggs of three seabird species, double-crested cormorant (Phalacrocorax auritus), Leach's storm-petrel (Oceanodroma leucorhoa), and Atlantic puffin (Fratercula artica) were collected at 4-yr intervals from 1968 to 1984, from colonies (4 to 10 eggs/colony) in eastern Canada (A: Great Island, Newfoundland; B: Kent Island C: Manawagonish Island and D: Machias Seal Island, Bay of Fundy; and E: Ile-aux-Pommes, St. Lawrence River) and analyzed for organochlorines. PCBs declined significantly in all species from the Bay of Fundy, and from site A, but not significantly at site E. Over the entire period, PCB residues were highest in the cormorant. [Pearce PA et al; Environ Pollut 56 (3): 217-35 (1989)] **QC REVIEWED**

NTOX - Channel catfish were obtained from Devil's Swamp (exposed fish), a river basin in southern LA heavily impacted by industrial complexes and hazardous waste sites. Reference fish were taken from LA State University's experimental Ben Hur aquaculture facility. The hepatic microsomal mediated O-dealkylation of various substituted alkoxyresorufins by the catfish were compared and correlated with polychlorinated biphenyl (PCB) contents from fat tissues of these fish. The most abundant PCB congeners found were pentachlorinated PCB (3900 ppb) followed by hexachlorinated (2800 ppb), tetrachlorinated (2400 ppb), heptachlorinated (540 ppb), octachlorinated (230 ppb), trichlorinated (130 ppb) and dichlorinated (40 ppb) biphenyls. The monochlorinated, nonochlorinated and decachlorinated biphenyls were represented in trace concn. Fatty tissue from reference fish were essentially devoid of PCB congeners. Specific activities and turnover numbers of 7-methoxyresorufin, 7-ethoxyresorufin, 7-pentoxyresorufin and benzyloxyresorufin O-dealkylases in Devil's Swamp microsomes of both male and female fish were significantly elevated relative to that of reference fish. When expressed per mg of protein, the degree of induction of these activities was notably higher in female catfish than

in male catfish. [Winston GW et al: J Environ Sci Health (B) 24 (3): 277-89 (1989)] **QC REVIEWED**

NTOX - To study the chronic effects of contaminated sediments on mortality, growth, gonad production and bioaccumulation in the urchin, Lytechinus pictus, urchins were exposed to 3 of the most contaminated sediment types in southern California and to a control sediment in the laboratory for 60 days in flow through experiments. Initial concentrations of polychlorinated biphenyls in the sediments used were very high (1118-3484 ng/g vs < 59 ng/g dry wt in the control), as were those of other contaminants. The sediments caused significant mortality and reduction of growth. Both male and female gonad production was also significantly decreased. Gonads accumulated up to 7.4 ppm polychlorinated biphenyls during the 60 day exposure period, but their concentrations of Cd, Cu and Zn were greatly reduced. [Thompson BE et al; Environ Toxicol Chem 8 (7): 629-37 (1989)] **QC REVIEWED**

NTOX - In order to investigate interspecific responses to pollutants, physiological and biochemical parameters were studied in 2 sp of Gobiidae under both natural and experimental conditions. In addition to higher mixed function oxidase activity, Gobius niger, collected in a heavily polluted port, had higher polychlorinated biphenyls residues (0.45 ug/g dry wt vs 0.23 ug/g dry wt) than another sp, Zosterisessor ophiocephalus, collected from a relatively clean lagoon. After 20 days of acclimatization to clean water, the 2 sp exhibited practically identical levels of mixed function oxidase activity and polychlorinated biphenyls residues. Subsequent exposure to polychlorinated biphenyls (Arochlor 1260) at 10 ug/l resulted in considerably higher mixed function oxidase activity in G niger than in Z ophiocephalus and the polychlorinated biphenyls residue level was 4 times higher in G niger than in Z ophiocephalus after 20 days of exposure. [Fossi C et al; Ecotoxicol Environ Safety 18 (1): 11-4 (1989)] **QC REVIEWED**

NTOX - Two groups of 12 female common seals (Phoca vitulina) were fed fish having high levels of polychlorinated biphenyl (PCB) contamination from the Wadden Sea (Group 1), or fish having low PCB contamination from the northeast Atlantic (Group 2) for almost 2 yr. Seals in Group 1 had a drastic reduction in plasma retinol concn as compared to those in Group 2 (30 to 55% reduction). The PCB-induced reduction in plasma retinol levels disappeared when seals were subsequently fed low-PCB Atlantic Ocean fish for 6 mo. Significant reductions of total and free thyroxine and triiodothyronine were also observed in Group 1. [Brouwer A et al; Aquatic Toxicol 15 (1): 99-106 (1989)] **QC REVIEWED**

NTOX - Regeneration experiments on the liver of flounder (Platichthys flesus L.) were performed to identify the role of diverse pollutants (chlorinated hydrocarbons including polychlorinated biphenyls) in the pathogenesis of the liver abnormalities observed during a 3-yr multidisciplinary survey in the Elbe estuary (Federal Republic of Germany). Flounder kept under contaminant-free conditions and fed ad libitum with uncontaminated food indicated initial and complete liver regeneration in 50% of the individuals after 20 days, and in 70% after 40 days. Signs of regeneration, diagnosed at the light and electron microscope level were accompanied by a significant decr in the concn of chlorinated hydrocarbons in the liver. Livers of flounder without regenerative signs maintained their high levels of contaminants. The

ultrastructural findings indicated that transfer of Elbe flounder into a contaminant-free environment induced incr activity of biotransformation and detoxification in the hepatocytes (tubular smooth endoplasmic reticulum, lysosomes). [Kohler A; Aquat Toxicol 14 (3): 203-32 (1989)] **QC REVIEWED**

NTOX - Rhesus monkeys exposed to polychlorinated biphenyl mixtures during gestation and lactation were tested on two-choice discrimination-reversal learning (DR). In the first experiment, offspring of mothers fed 1.0 ppm Aroclor 1248 (avg exposure 20.7 + or - 3.1 mo), and offspring born 1.5 yr after maternal exposure to 2.5 ppm Aroclor 1248 ended (avg exposure 18.2 + or - 1.7 mo) did not differ from controls on spatial, color or shape discrimination-reversal problems. In the second experiment, offspring of mothers fed 0.25 or 1.0 ppm Aroclor 1016 (avg exposure of 21.8 + or - 2.2 mo) and offspring born 3 yr after maternal exposure to 2.5 ppm Aroclor 1248 ended were tested on the same spatial, color and shape problems, but a spatial problem with color and shape as irrelevant cues was inserted after the initial spatial problem. Performance of the high dose Aroclor 1016 offspring was impaired on the initial spatial problem, and facilitated on the shape problem. Performance of the Aroclor 1248 postexposure offspring was facilitated on the shape problem. [Schantz SL et al; Neurotoxicol Teratol 11 (3): 243-50 (1989)] **QC REVIEWED**

NTOX - Different combinations of 2,5,2',5'- and 3,4,3',4'-polychlorinated biphenyls and Aroclor 1254 were applied to human lymphocyte cultures, which were subsequently examined for chromosome breakage, rearrangements, sister-chromatid exchange, and mitotic delay. Results were compared to similar cultures treated with the known mutagen cyclophosphamide. In one experiment, parallel cultures were exposed to a final culture concn of either 10-4, 10-3, 10-2, or 10-1 ug/ml of 3,4,3',4' or to a 1.0 ug/ml dose of 2,4,2',5' and to either 10-3 ug/ml or 10-5 ug/ml of cyclophosphamide or to 25, 20, 10 or 5 ng/ml mitomycin C. Cells were also exposed to combinations of 2,5,2',5'- and 3,4,3',4'-polychlorinated biphenyl using either a combination of 1 ug/ml 2,5,2'5'- with 10-2, 10-3, 10-4 or 10-5 ug/ml 3,4,3',4'-polychlorinated biphenyl or a combination of 10-5 ug/ml 3,4,3'4'-polychlorinated biphenyl with 10-1, 10-2, or 10-3 ug/ml 2,5,2'5'-polychlorinated biphenyl. In other experiments, parallel cultures were treated with either 1 ug/ml or 10-1 ug/ml 2,4,5,2',4',5'-polychlorinated biphenyl as well as to a combination of 10-5 ug/ml 3,4,3',4' and 10-1 ug/ml 2,4,5,2',4',5'-polychlorinated biphenyl. In addition, either Aroclor 1254 or a fish extract containing Aroclor 1254 was added to parallel cultures at 1.1 ug/ml, 1.1X10-1 ug/ml or 1.1X10-2 mg/ml. Results showed that one planar polychlorinated biphenyl congener, 3,4,3',4'-tetrachlorobiphenyl, caused dose-related chromosome breakage in human lymphocytes exposed in vitro to 0.1-10-4 ug/ml. In contrast, the non-planar 2,5,2'5'- polychlorinated biphenyl, did not cause chromosome damage in comparable tests even at concn as high as 1 ug/ml. When the 3,4,3',4' congener at a concn lower than that which causes chromosome breakage (10-5 ug/ml) was combined with a non-clastogenic concn of the 2,5,2'5' congener, the chromosomal damage observed was far in excess of what one would expect from higher doses of the 3,4,3',4' congener alone. [Sargent L et al; Mutat Res 224 (1):

79-88 (1989)] **QC REVIEWED**
HTXV - ND
NTXV - ND
ETXV - ND
NTP - ND
IARC - ND
POPL - Persons with skin diseases and chronic liver diseases and women of child-bearing age /are at special risk in facilities/ manufacturing or using PCBs. [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1755] **PEER REVIEWED**
POPL - Those groups at particular risk for PCB exposure include ... individuals consuming large amounts of contaminated fish, such as sport fishermen, and nursing infants who, per kg body weight, may accumulate significant body burdens from the levels in human breast milk. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-79 (1980) EPA 440/5-80-068] **PEER REVIEWED**
ADE - DURING MARCH 1964 AND FEBRUARY 1970, 48 OF 169 GOLDEN EAGLES FROM 22 STATES WERE FOUND TO CONTAIN PCBS IN EITHER BRAIN, HEART, KIDNEY, LIVER, MUSCLE, OR FAT, IN CONCN RANGING FROM LESS THAN 1 TO 19 UG/G ON A WET BASIS. [IARC MONOGRAPHS. 1972-PRESENT V18 63 (1978)] **PEER REVIEWED**
ADE - /IN 1970/ ... THE MEAN PCB LEVEL IN HUMAN MILK IN TWO CALIFORNIA CITIES WAS ABOUT 0.06 UG/ML OF WHOLE MILK. ... ANALYSIS OF LIPID FRACTION OF 80 SAMPLES OF HUMAN MILK FROM VARIOUS AREAS OF THE USA SHOWED THAT ALL EXCEPT 2 HAD CONCN ... FROM 0.4-10.6 UG/G. THE AVERAGE CONCN IN ALL SAMPLES WAS APPROX 1.7 UG/G. [IARC MONOGRAPHS. 1972-PRESENT V18 64 (1978)] **PEER REVIEWED**
ADE - FORTY-THREE PERCENT OF 723 PLASMA SAMPLES FROM PERSONS IN SOUTH CAROLINA NOT OCCUPATIONALLY EXPOSED TO PESTICIDES WERE FOUND TO CONTAIN PCBS, WITH A MAXIMUM OF 0.029 UG/ML. [IARC MONOGRAPHS. 1972-PRESENT V18 65 (1978)] **PEER REVIEWED**
ADE - Polychlorinated biphenyls are stored in body fat and not readily excreted except in breast milk and possibly through the placenta. [MARTINDALE. EXTRA PHARMACOPEIA 28TH ED 1982 , p. 831] **PEER REVIEWED**
ADE - Polychlorinated biphenyls (PCBs) are readily absorbed through the gut, respiratory system and skin. /PCBs/ may initially concentrate in the liver, blood, and muscle mass, but long-term storage in mammals is primarily in adipose tissue and skin. ... [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-31 (1980) EPA 440/5-80-068] **PEER REVIEWED**
ADE - PCBs which are readily metabolized are also rapidly excreted in the urine and bile. Excretion in urine is most prominent for the least chlorinated, while bile becomes the more significant route of excretion for more highly chlorinated isomers. Those isomers which are most refractory to metabolism accumulate for increasing periods of time in fatty tissues. Highly chlorinated isomers are accumulated almost indefinitely. [USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.C-32 (1980) EPA 440/5-80-068] **PEER REVIEWED**
ADE - Animal studies have shown that PCB's can cross the placental barrier and are excreted in the mother's milk. [IARC MONOGRAPHS. 1972-PRESENT

V18 37 (1978)] **PEER REVIEWED**

ADE - In a plant in the United States the PCB plasma levels of workers assembling capacitors and transformers ranged from 10.0-2500 ppb. The plasma concentration increased with the intensity and duration of exposure. [ENCYC OCCUPAT HEALTH & SAFETY 1983 , p. 1753] **PEER REVIEWED**

ADE - Polychlorinated biphenyl (PCB) concentrations in the blood of mothers who were occupationally exposed to PCBs in the capacitor manufacturing facility, and their children, were analyzed from 1975 to 1979. The factory terminated PCB use in 1972, and environmental PCBs were eliminated artificially. Despite this, blood PCB levels of the mothers were very high, ie, 10-100 times higher than that of non-occupationally exposed persons. ... By a present investigation which continued during a 5 yr period, the PCB levels in blood of children were influenced greatly by the duration of breast-feeding, but showed little relationship to the PCB levels in maternal blood. The PCB exposure period of the mothers, time of birth, and age of the children were less clearly related to the PCB levels in the children. The PCB concentration in the children's blood decreased at a constant rate and was independent of their blood PCB levels. A similar result was noted for their mothers' PCB levels. A slight difference, however, was found in the rate of decrease of blood PCB levels between the mothers and children. The results of questionnaire research on the health conditions and the medical examinations for the children showed that frequency of complaints, eg, red eye, fever, itchy skin, and carious teeth, related favorably to the duration of breast-feeding. Less severe findings, ie, decay of nails, pigmentation, mottled enamel, carious teeth, which were typical symptoms in Yusho patients, were observed in some children. ... [Kunita N, Hara I; Arch Environ Health 39 (5): 368-75 (1984)] **PEER REVIEWED**

ADE - Mayflies (Hexagenia limbata) collected from May to Nov 1986 from Lake St. Clair at temperatures of 10 to 20 deg C were exposed in 200 ml test chambers to a polychlorinated biphenyl, (14)C-2,4,5,2',4',5'-hexachlorobiphenyl, in flow-through water and sediment exposure tests. In the water exposure tests where the animals were in artificial burrows of stainless steel screen, the infusion rate was 100 ml/hr of dosed water, with no sediment present. Animals were removed after 1, 2, 4, and 6 hr exposure for radioanalysis. Animals remaining in the exposure chamber after the uptake phase were removed and placed in uncontaminated sediment for elimination for studies for 1, 3, 5, 7, and 14 days. The accumulation from sediment was measured by sorbing the radiolabeled compounds onto sediment in an aqueous slurry overnight. Exposed organisms were removed from the sediment at approximately 1, 3, 5, 7, and 14 days and were radioanalyzed by scintillation counting. The seasonal uptake and elimination rate constants for H limbata, respectively, were: 47.5 + or - 23.9 ml/g/hr and 0.007 + or - 0.001/ hr in May (10 deg C); 44.2 + or - 8.0 ml/g/hr and 0.005 + or - 0.002/hr in Jun (15 deg C); 40.8 + or - 37.3 ml/g/hr and 0.005 + or - 0.001/hr in Jul (15 deg C); 40.8 + or - 37.3 ml/g/hr and 0.007 + or - 0.001/hr in Aug (20 deg C); 128.7 + or - 20.3 ml/g/hr and 0.015 + or - 0.003/hr in Sept (20 deg C); 95.0 + or - 17.3 ml/g/hr and 0.017 + or - 0.002/hr in Sept 30 (20 deg C); and 45.5 + or - 16.1

ml/g/hr and 0004 + or - 0.0006/hr in Nov (10 deg C). Reported values for seasonal uptake rate constants have been corrected for sorption to dissolved organic carbon. Seasonal uptake clearance rate constants from sediment for H limbata for Jun and Aug, respectively, were: 0.030 + or - 0.01/hr (15 deg C) and 0.015 + or - 0.003/hr (20 deg C). [Landrum PF, Poore R; J Great Lakes Res 14 (4): 427-37 (1988)] **QC REVIEWED**

ADE - The uptake of polychlorinated biphenyl (PCB) congeners was investigated in leaf composites and final fruits of four crop species at two alluvial mud sites (a control plot in the flood plain of the Normanskill, NY, and an experimental plot on Patroon Island, Albany, NY).

Versar INC.

APPENDIX E

Feasibility Study Documentation

Naval Station Roosevelt Roads
Site 15
Project No. 5295.4.1
Cost Worksheet for Remediation Options

CAPITAL COST ITEMS	COSTS
Alternative A: Excavation and Transport to Incineration Facility	
SUBTOTAL CAPITAL COSTS	$884,550
QA/QC (5%)	$44,228
TOTAL CAPITAL COSTS	$928,778
ENGINEERING DESIGN (10%)	$92,878
CONSTRUCTION MANAGEMENT (15%)	$139,317
STARTUP (10%)	$92,878
BONDS AND PERMITS (2.5%)	$23,219
LEGAL FEES (3%)	$27,863
CONTINGENCIES (20%)	$185,756
TOTAL ADJUSTED CAPITAL COSTS	$1,490,688
Alternative B: Excavation and Transport to Licensed Landfill Facility	
SUBTOTAL CAPITAL COSTS	$253,150
QA/QC (5%)	$12,658
TOTAL CAPITAL COSTS	$265,808
ENGINEERING DESIGN (10%)	$26,581
CONSTRUCTION MANAGEMENT (15%)	$39,871
STARTUP (10%)	$26,581
BONDS AND PERMITS (2.5%)	$6,645
LEGAL FEES (3%)	$7,974
CONTINGENCIES (20%)	$53,162
TOTAL ADJUSTED CAPITAL COSTS	$426,621
Alternative C: On-Site Incineration	
SUBTOTAL CAPITAL COSTS	$706,050
QA/QC (5%)	$35,303
TOTAL CAPITAL COSTS	$741,353
ENGINEERING DESIGN (10%)	$74,135
CONSTRUCTION MANAGEMENT (15%)	$111,203
STARTUP (10%)	$74,135
BONDS AND PERMITS (2.5%)	$18,534
LEGAL FEES (3%)	$22,241
CONTINGENCIES (20%)	$148,271
TOTAL ADJUSTED CAPITAL COSTS	$1,189,871

Naval Station Roosevelt Roads
Site 15
Project No. 5295.4.1
Cost Worksheet for Remediation Options

CAPITAL COST ITEMS	UNIT COST	QUANTITY	SUBTOTAL COST	HEALTH AND SAFETY PROTECTION	CAPITAL COSTS	PRIMARY REFERENCE
Alternative A: Excavation and Transport to Incineration Facility						
Excavation	$3.00 /ton	350 tons	$1,050	C	$1,050	Vendor Quote
Transportation	$500.00 /ton	350 tons	$175,000	none	$175,000	Vendor Quote
Disposal at Licensed Incineration Facility	$2,000.00 /ton	350 tons	$700,000	none	$700,000	Vendor Quote
Backfill, installed	$10.00 /ton	350 tons	$3,500	none	$3,500	Vendor Quote
Concrete Gritblasting	$5,000 /job				$5,000	Vendor Quote
SUBTOTAL CAPITAL COSTS					$884,550	
QA/QC (5%)					$44,228	
TOTAL CAPITAL COSTS					$928,778	
Alternative B: Excavation and Transport to Licensed Landfill Facility						
Excavation	$3.00 /ton	350 tons	$1,050	C	$1,050	Vendor Quote
Transportation	$500.00 /ton	350 tons	$175,000	none	$175,000	Vendor Quote
Disposal at Licensed Landfill Facility	$196.00 /ton	350 tons	$68,600	none	$68,600	Vendor Quote
Backfill, installed	$10.00 /ton	350 tons	$3,500	none	$3,500	Vendor Quote
Concrete Gritblasting	$5,000 /job				$5,000	Vendor Quote
SUBTOTAL CAPITAL COSTS					$253,150	
QA/QC (5%)					$12,658	
TOTAL CAPITAL COSTS					$265,808	
Alternative C: On-Site Incineration						
Excavation	$3.00 /ton	350 tons	$1,050	C	$1,050	Vendor Quote
Thermal Treatment	$2,000.00 /ton	350 tons	$700,000	C	$700,000	Vendor Quote
Concrete Gritblasting	$5,000 /job				$5,000	Vendor Quote
SUBTOTAL CAPITAL COSTS					$706,050	
QA/QC (5%)					$35,303	
TOTAL CAPITAL COSTS					$741,353	

Versar Inc.

RR-00206-03.13-05/15/92

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Versar, Inc. Phase II Technical Services Group	☐	Telefax Phone No.	(703)642-6810
		Confirming Phone No.	(703)750-3000, Ext. _____

(C)

Tri County Industries

(301) 937-8611
Fax # 937-8028
F.I.D 52-1340142

5005 Powder Mill Road
P.O. Box 1157
Beltsville, MD 20705

FACSIMILE TRANSMISSION

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NOTES:

Price for PCB contaminated soil disposal in Puerto Rico. (SD)
Price based on pcb levels and no other listed wasts involved. (metals, Solvents)

Price per Ton $696.00
plus barge transfer fee (minimal)

Material Profile Sheet

WILLIAMS PROPOSAL No. _____ DATE _____
(for Williams use only)

INSTRUCTIONS:

A completed Material Profile Sheet must be filled out and submitted before a written price quotation can be issued. Please note that customer is the party responsible for payment. Answers must be typewritten or printed in ink.

(1) GENERATOR Name: US NAVY
Address:
Contact: Telephone: ( )

(2) CUSTOMER Name: US NAVY
Address:
Contact: Telephone: ( )

(3) CONSULTANT Name: VERSAR INC – KENNETH SALEM
Address: 6850 VERSAR CENTER SPRINGFIELD VA 22151
Contact: Telephone: (703) 642 6722

(4) SITE LOCATION Name: PUERTO RICO
Address:
Contact: Telephone: ( )

(5) ANTICIPATED QUANTITY 2500 (tons) _____ (volume)

(6) TYPE OF CONTAMINATION _____ Gasoline, _____ No. 2 Fuel Oil
_____ Heavy Oil, _____ Other: PCB 0-1500 ppm w 200 ppm AVG

(7) ANALYTICAL DATA (attach hard copy of Engineering Report)

Benzene _____ ppm Toluene _____ ppm Total Lead _____ ppm
Xylene _____ ppm Ethyl Benzene _____ ppm % Moisture _____
TPH (Method _____) _____ ppm
Average Concentration _____ ppm

(8) SOIL CHARACTERISTICS

Type: _____ Clay, _____ Sandy Clay, X Sand, _____ Silty Sand
Texture: X Dry, _____ Moist, _____ Wet, _____ Saturated

(9) CLEAN-UP LEVELS 10 ppm by Method _____

(10) ESTIMATED START DATE SPRING '92

(11) ADDITIONAL INFORMATION

I hereby certify that the above description is complete and accurate to the best of my knowledge.

SIGNED: Kenneth Salem CHEMICAL ENGINEER
(Title)

C

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From: Maurizio Gabbani

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Marietta, GA [illegible]

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HazWaste

HazLabs Incorporated
A HazWaste Company

September 4, 1991

Mr. Ken Salen
Versar, Inc.
6800 Versar Center
Springfield, VA 22151

Dear Mr. Salen,

Please find enclosed the information you requested on HazLab's "Treatability Studies for the Aerobic Bioremediation of Contaminated Soils". This document presents our approach to the evaluation of the potential for using biological treatment as a remediation technology.

We apologize for the delay in submitting this information. If you have any questions please contact me or Jack Mizner at (404) 988-8184.

Sincerely,

Maurizio F. Giabbai, PhD.
President

MFG/tow

cc: Mr. Jack Mizner, Jr., Senior Environmental Engineer

B07/aerbiore.cp

2264 NORTHWEST PARKWAY • SUITE F • MARIETTA, GEORGIA 30067
404-988-8184
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TREATABILITY STUDIES FOR AEROBIC BIOREMEDIATION OF CONTAMINATED SOILS

SUBMITTED TO: Versar, Inc.
6800 Versar Center
Springfield, VA 22151
Attn: Mr. Ken Salen

SUBMITTED BY: HazLabs, Inc.
2264 Northwest Parkway
Suite F
Marietta, GA 30067

September 4, 1991

807/aerbfore.cp

TREATABILITY STUDIES FOR AEROBIC BIOREMEDIATION OF CONTAMINATED SOILS

I. INTRODUCTION

Biodegradation is an important environmental process which occurs naturally and results in the breakdown of organic compounds either aerobically or anaerobically into by-products of microbial metabolism such as CO_2, H_2O, CH_4, and inorganic salts. Microorganisms (bacteria, actinomycetes, and fungi) make up the most significant group of organisms involved in biodegradation.

Soil environments contain a diverse microbial community, which, under the proper conditions, can degrade a wide variety of organic compounds, including those considered toxic or recalcitrant. Degradation of these toxic or recalcitrant compounds, however, may be slow, especially when these compounds are introduced into the soil environment in large quantities (i.e. accidental releases such as spills or ruptured tanks). In such cases the microbial community is not adapted to the particular substrate and requires an acclimation period to develop the necessary enzyme systems to degrade the substrate. This process is slow and may take many years to develop a population capable of reducing organic contaminants to regulatory levels. Additionally, the proper physical and chemical conditions must be present to develop a microbial community capable of degrading recalcitrant compounds, such as pesticides, petroleum products, and aromatic compounds. However, by applying scientific principles and good engineering practices, conditions can be created in which the majority of organic wastes can be degraded by soil microorganisms through a process of bioremediation in a reasonable amount of time.

Bioremediation is a term which describes the use of microorganisms to degrade or detoxify environmental contamination to concentrations below regulatory limits. Aerobic, anaerobic or facultative pathways may be utilized. A variety of systems exist to accomplish this, and range from simple to in situ systems such as soil tilling and composting to more complicated designs such in-vessel slurry reactors. The ultimate goal is convert organic wastes into biomass and harmless byproducts of microbial metabolism.

The advantages of soil bioremediation are:

1) It is often more cost-effective than other remediation methods.
2) Less liability (i.e., transportation) is incurred if the waste is treated on-site.
3) The soil is rendered non-hazardous, and can be used for other purposes.

The chief disadvantages of soil bioremediation is the length of time that may be required to reduce contamination to necessary levels.

Bioremediation, like any other technology, is not a panacea for the treatment of all contaminated soils. A thorough characterization of the contaminant, the soil, and site must be conducted, and laboratory and field investigations should be performed before a decision can be made to apply this approach to site restoration.

This report presents a simple tiered approach to conducting treatability studies to determine if bioremediation is an appropriate technology, and if so to develop the necessary design parameters to insure that it is successfully applied. This four phased approach consists of: 1) Soil Characterization, 2) Bioremediation screening Tests, 3) Optimization Studies, 4) Pilot-scale Testing. Each of these phases and a range of costs is presented below.

II. MAJOR PHASES OF BIOREMEDIATION TREATABILITY STUDY

IIa. Phase I- Soil and Waste Characterization

Before proceeding with treatability experiments, the extent and degree of the contamination must be assessed. This includes analyses to identify and quantify the hazardous materials, and to establish the physical and chemical characteristics of the soil matrix. These analyses include:

- NUTRIENTS CONCENTRATIONS - (phosphorus, nitrogen, potassium, carbon, trace elements).
- ORGANIC CONSTITUENTS CHARACTERIZATION - The characterization will include the qualitative and quantitative analysis of toxic organic compounds (e.g., BTEX, Chlorinated Solvents, PAHs Phenols, etc.) that will be tested for biodegradability. Additional analyses will be conducted to gather information on the other organic constituents present in the soil matrix (e.g., TOC, TOX, etc.)
- BACTERIAL CONCENTRATIONS - Estimates of the type and numbers of indigenous bacteria provide an indication of whether cultured micro-organisms are required to remediate the site.
- HEAVY METALS CHARACTERIZATION - This analysis determines the presence of any toxic metals.
- PHASE ANALYSIS OF CONTAMINANTS - This analysis will reveal to what extent the contamination is present in the solid, liquid, or vapor phases.

- SOIL CHARACTERISTICS
  - % moisture
  - pH
  - REDOX potential
  - Oxygen concentration
  - Soil type
  - Temperature

Based upon the above analyses a decision will be made as to whether bioremediation is a feasible option, and, if so, how best to proceed with its evaluation.

Costs for this phase varies depending on the type and extent of the contamination and the number of samples required for a full characterization. Typical costs vary from $2,000 - $10,000.

IIb. Phase II- Bioremediation Screening Tests

In this phase several options are evaluated to determine how to proceed with biological treatment of the soil. These tests will be conducted in Biometer flasks.

A Biometer flask is an unmixed, aerated batch reactor, in which bacterial respiration is determined by quantifying CO_2 production. Cumulative respiration of a bacterial population is related to its growth, reproduction, and ability to metabolize a particular substrate (food) source). By varying factors such as nutrients, the ability of a microbial population to degrade a contaminated soil can be investigated.

At a minimum 4 treatments consisting of 4 biometer flasks per treatment are required for this screening process. The 4 treatments are:

1) ABIOTIC CONTROL = contaminated soil & mercuric chloride. This treatment is necessary to determine if there is non-biological production of CO_2 which could lead to false conclusions about the biotreatability potential.

2) CONTROL = contaminated soil only. This treatment measures the ability of the indigenous bacterial population to degrade the contaminants.

3) NUTRIENT TREATMENT = contaminated soil & nutrients. This treatment measures the effect that nutrient addition has on bacterial degradation of the contaminants.

4) BACTERIAL TREATMENT = contaminated soil & nutrients & cultured bacteria. This treatment measures the effect that the addition of an acclimated bacterial strain has in the degradation of the contaminants.

For each treatment 4 identical biometer flasks are prepared. The 16 biometer flasks are then incubated under identical conditions. Table 1 below presents a matrix for this experimental protocol. The Xs in Table 1 indicate the time when each flask within a particular treatment will be sacrificed. At this time the soil mixture within each flask will be analyzed. This analysis will include the concentration of contaminants, and the nutrient concentration. Bacterial numbers, if desired by the client, can also be measured at this time. For each flask CO_2 production will be measured every 2 to 3 days depending in the rate of metabolism. This experimental approach will provide information on: 1) respiration rate, 2) degradation rate of the contaminants, 3) nutrient utilization, and 4) change in bacterial population.

By comparing different treatments one can evaluate conditions which will promote the quickest degradation of the soil contamination.

Costs for this phase of study vary between $ 5,000.00 and $ 10,000.00.

Table 1. Experimental Matrix for Screening Tests

DAYS	ABIOTIC CONTROL				CONTROL				NUTRIENT TREATMENT				BACTERIAL TREATMENT			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
7	X				X				X				X			
14		X				X				X				X		
21			X				X				X				X	
28				X				X				X				X

IIc. Phase III Optimization Studies

Based on the results obtained from Phase II testing, additional experiments will be conducted during Phase III to optimize variables, such as nutrient addition, pH, bacterial addition, and soil moisture. Data gathered during this phase of experimentation will permit us to establish the relationship between the variables which affect biodegradation of the soil contamination, to optimize this process, and to predict removal rates and removal efficiencies of the soil contaminants.

Testing will be conducted in biometer flasks, as described in Phase II, and in specially designed lysimeters. These lysimeters are larger volume reactors that will be used to verify the efficiency at the selected " best" treatment.

Costs associated with this phase will vary with the clients needs, the results from phases I, and II the complexity of the soil matrix and environmental conditions. Costs will vary from $7,000.00 to $ 15,000.00.

IId. Phase IV Pilot Testing

On site pilot testing will be conducted, based on the results from the first three phases, to verify the laboratory derived operating parameters. The pilot scale unit will be specially designed based on the proposed full scale remediation design.

Cost proposals will be submitted at the end of Phase III testing for the pilot scale study.

III. COST PROPOSAL SUMMARY

The cost associated for each phase identified above are summarized hereafter. These include labor, analysis, and material/supplies costs and fees. Upon request, a detailed cost proposal will be prepared by taking into account the specific needs of each project (e.g., sample disposal, etc.). The following cost proposal is presented in dollar ranges for each phase and should be used only as an estimate:

Phase I	$ 2,000 - $10,000
Phase II	$ 5,000 - $10,000
Phase III	$ 7,000 - $15,000
Phase IV	QUOTE

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