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REMEDIAL INVESTIGATION /FEASIBILITY STUDY (RI/FS) FOR OPERABLE UNIT 9 (OU-9) (AREA A MEDIA OTHER THAN GROUNDWATER) for NAVAL AIR WARFARE CENTER WARMINSTER, PENNSYLVANIA

Volume I

Northern Division
Naval Facilities Engineering Command
Contract No. N62472-90-D-1298
Contract Task Order 0290

APRIL 2000

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April 28, 2000

Project Number 7603

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Reference: CLEAN Contract No. N642472-90-D-1298
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Subject: Remedial Investigation/Feasibility Study Report for Operable Unit 9 (OU-9)
Area A Media Other than Groundwater
Former Naval Air Warfare Center (NAWC) Warminster, Pennsylvania

Dear Mr. Monaco:

Enclosed please find two copies of the final RI/FS report for Area A soils, surface water, and sediment. This version incorporates Navy and other technical review comments. Copies are being sent to the individuals identified in the distribution list.

Please contact me if you have any questions or comments.

Sincerely,

Neil Teamerson

Neil Teamerson
Project Coordinator

ANT/NFS

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PHIL-14093

REMEDIAL INVESTIGATION/FEASIBILITY STUDY (RI/FS) REPORT
FOR OPERABLE UNIT 9 (OU-9)
(AREA A MEDIA OTHER THAN GROUNDWATER)

NAWC WARMINSTER

COMPREHENSIVE LONG - TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) PROGRAM

Submitted to:
Northern Division
Environmental Branch, Mail Stop No. 82
Naval Facilities Engineering Command
10 Industrial Highway
Lester, Pennsylvania 19112-5094

Submitted by:
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GLOSSARY

As	Arsenic
ARARs	Applicable or relevant and appropriate requirements
AWQC	Ambient Water Quality Criterion
B(a)A	Benzo(a)anthracene
B(a)P	Benzo(a)pyrene
B(a)F	Benzo(b)fluoranthene
BCF	Bioconcentration factor
BCT	BRAC Clean-up Team
Be	Beryllium
bgs	Below ground surface
BLRA	Baseline Risk Assessment
B&R	Brown & Root Environmental
BRAC	Base Realignment and Closure
BTAG	Biological Technical Assistance Group
BTEX	Benzene, toluene, ethylbenzene, and xylenes
BTV	Benchmark toxicity value
CCl_4	Carbon Tetrachloride
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERFA	Community Environmental Response Facilitation Act
cis-1,2-DCE	Cis-1,2-Dichloroethene
CLP	Contract Laboratory Program
COC	Chemical of concern
COPC	Chemical of potential concern
Cr	Chromium
Cr^{+6}	Hexavalent Chromium
CRDL	Contract- required detection level
CRQL	Contract- required quantitation level

GLOSSARY (continued)

CSF	Cancer Slope Factor
CTO	Contract Task Order
Cu	Copper
D	Dump
DAF	Dilution and attenuation factor
D(a,h)A	Dibenz(a,h)anthracene
1,1-DCA	1,1-Dichloroethane
1,4-DCB	1,4-Dichlorobenzene
4,4'-DDD	1,1bis(4-Chlorophenyl)2,2-Dichloroethene
4,4'-DDE	1,1bis(4-Chlorophenyl)1,1-Dichloroethylene
4,4'-DDT	1,1bis(4-Chlorophenyl)Trichloroethene
DEHP	Bis(2-ethylhexyl)phthalate
DG	Disturbed ground
DNAPL	Dense non-aqueous phase liquid
DOD	Department of Defense
EBS	Environmental baseline survey
ECD	Electron capture detector
EE/CA	Engineering evaluation/cost analysis
EEI	Environmental effects index
EEQ	Environmental effects quotient
EIS	Environmental Impact Statement
EM	Electromagnetic
EPA	United States Environmental Protection Agency
EPC	Exposure point concentration
EPIC	Environmental Photographic Interpretation Center
ERA	Ecological risk assessment
ER-L	Effects range-low
EX	Excavation

GLOSSARY (continued)

Fe	Iron
FID	Flame ionization detector
FLRA-BC	Federal Land Re-Use Authority - Bucks County
FOC	Fractional organic carbon
FS	Feasibility study
GC	Gas chromatograph
gpm	Gallons per minute
GPS	Global positioning system
GS	Ground scar
HI	Hazard Index
HHRA	Human health risk assessment
HHS	Health & Human Services
HNUS	Halliburton NUS Corporation
HPCDD	Heptachlorinated dibenzo-p-dioxin
HPCDF	Heptachlorinated dibenzofuran
HRS	Hazard Ranking System
HQ	Hazard quotient
ICP	Inductively coupled plasma
ICR	Incremental cancer risk
ID	Inner diameter
IEUBK	Integrated Exposure and Update Biokinetic Model
IM	Impoundment
I(1,2,3-cd)P	Indeno(1,2,3-cd)pyrene
IRP	Installation Restoration Program
KD	Partioning coefficient
K_{oc}	Organic carbon/chemical partitioning coefficient
K_{ow}	Octanol/water partitioning coefficient
LOAEL	Lowest observed adverse effect level

GLOSSARY (continued)

PBC	Public benefit conveyance
PCBs	Polychlorinated biphenyls
PCE	Tetrachoroethene
PE	Polyethylene
PECDD	Pentachlorinated dibenzo-p-dioxin
PECDF	Pentachlorinated dibenzofuran
PID	Photoionization detector
PQL	Practical quantitation limit
QA/QC	Quality assurance/quality control
RAB	Restoration Advisory Board
RBC	Risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfD	Risk reference dose
RI	Remedial investigation
RME	Reasonable maximum exposure
ROD	Record of Decision
S	Structure
SARA	Superfund Amendments and Authorization Act
Sb	Antimony
SB	Soil boring
SCS	Soil Conservation Science
SD	Sediment
SDA	Surface disposal area
SI	Site inspection
SMC	Science Management Corporation
SOW	Statement of work
SQC	Sediment quality criteria
SS	Surface soil

GLOSSARY (continued)

SSLs	Soil screening levels
SW	Surface water
TAL	Target Analyte List
TBC	To be considered
1,1,1-TCA	1,1,1-Trichloroethane
1,1,2-TCA	1,1,2-Trichloroethane
TCE	Trichloroethene
TCDD	Tetrachlorinated dibenzo-p-dioxin
TCDF	Tetrachlorinated dibenzofuran
TCL	Target Compound List
TCLP	Toxicity characteristic leaching procedure
TEFs	Toxicity Equivalent Factors
TIC	Tentatively identified compound
TOC	Total organic carbon
TP	Test pit
TPH	Total petroleum hydrocarbon
TR	Trench
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper confidence limit
USGS	United States Geologic Survey
UST	Underground storage tank
ug/kg	Micrograms per kilogram
ug/l	Micrograms per liter
UCL	Upper confidence limit
UTL	Upper tolerance limit
VOCs	Volatile organic compounds
WMA	Warminster Municipal Authority
Zn	Zinc

EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

In response to Contract Task Order No. 290 under Contract N62472-90-D-1298, Tetra Tech NUS, Inc. (TtNUS) is submitting this remedial investigation (RI) and feasibility study (FS) report for Area A media other than groundwater (Operable Unit 9 or OU-9) at the Naval Air Warfare Center (NAWC) (formerly the Naval Air Development Center), Warminster, Pennsylvania. OU-9 addresses soil, surface water, and sediment associated with Area A. Groundwater in the vicinity of Area A is being addressed under OU-1. This work is part of the Navy's Installation Restoration (IR) Program, which is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures, as needed.

SCOPE AND OBJECTIVES

The main areas of concern at NAWC Warminster involve several inactive waste sites that have been grouped into four general areas (Areas A, B, C, and D) for investigative purposes. The area of concern for this report, Area A, comprises Sites 1, 2, and 3, and the Impoundment Area and lies in the northwestern corner of the base, west of Jacksonville Road. Based on preliminary RI results, several soil removal actions were conducted at OU-9 in 1998. The objectives of the RI were to describe the nature and extent of contamination at OU-9 after the removal actions were performed and to provide a baseline risk assessment based on this information. In addition, the RI evaluates potential sources of groundwater contamination within Area A. The results of the risk assessment were used to determine whether additional response actions are warranted for the Area A sites.

Environmental investigations at Area A were conducted in several long-term remedial phases. Three separate investigations, Phases I, II, and III, were performed at Area A between October 1989 and October 1999. This report addresses Sites 1, 2, and 3 and the Impoundment Area only. It includes the results of additional surface and subsurface investigations performed at Area A since the removal actions for Area A soils were performed. To the extent practicable, the results of all RI phases have been incorporated into this report; however, the report primarily focuses on the Phase III investigation.

FACILITY HISTORY AND DESCRIPTION

The former NAWC Warminster property is located in the township of Warminster, Bucks County, Pennsylvania. The total area of the facility is approximately 734 acres. The facility lies in a populated suburban area surrounded by private homes, various commercial and industrial activities, and a golf course. On-base areas include various buildings and other complexes connected by paved roads, the runway and ramp area, mowed fields, and a small wooded area.

Commissioned in 1944, NAWC Warminster's main mission was research, development, testing, and evaluation for naval aircraft systems. NAWC Warminster also conducted studies in anti-submarine warfare systems and software development. Historically, wastes were generated during aircraft maintenance and repair, pest control, fire-fighting training, machine and plating shop operations, spray painting, and various materials research and testing activities in laboratories. These wastes included paints, solvents, sludges from industrial wastewater treatment, and waste oils.

Under the Base Realignment and Closure (BRAC) Program, the Department of Defense (DOD) realigned NAWC Warminster. The realignment was completed in September 1996 and the facility property was turned over to the Bucks County Federal Land Reuse Authority (FLRA). The FLRA is currently coordinating reuse planning for the base property, and most Navy activities have been eliminated.

AREA A BACKGROUND INFORMATION

The suspected sources within Area A are found in the northwestern corner of the fenced facility bordering an industrial/commercial area. Area A is roughly 1,200 feet by 270 feet in size and covers approximately 7.4 acres. An unnamed tributary of Little Neshaminy Creek is located north of Area A, and the NAWC Warminster wastewater treatment facility, former jet fuel storage area, and parking lots are immediately to the south.

Site 1

Site 1 is located on a portion of the facility lying northwest of Jacksonville Road, adjacent to the wastewater treatment plant. The site is within 1,000 feet of an off-site food processing facility and within 300 feet of an unnamed tributary that flows to Little Neshaminy Creek. Site 1 reportedly was operated as a burn pit within an eroded ravine from 1948 to 1950. Various wastes such as paints, oils, asphalt, roofing material, solvents, scrap metals, and unspecified chemicals were burned within this pit. Based on historical aerial photos, a trench, a ground scar, disturbed ground, and mounded material were located in the pit area during the time period from the late 1950s to early 1970s. After use of Site 1 was discontinued, the area was covered with soil from an on-base source. The quantity of wastes deposited or burned was unknown. The estimated area of Site 1 is approximately 2,500 square feet.

Site 2

Site 2 is located southeast of Site 1 and may have received industrial wastewater sludges from the former impoundment area. The site consisted of two disposal trenches, ground scars, and mounded material; each trench was allegedly about 12 feet wide by 200 feet long by 8 feet deep. These features, evident in aerial

photos from the 1950s, were no longer evident by the mid-1960s. This area is bordered by Site 1 to the west, the jet fuel storage area to the south, the existing guardhouse to the east, and the base fenceline to the north. A small stream that flows to the northwest is adjacent to the northeastern side of Site 2. Upon closure, the site was covered with 2 feet of fill, regraded, and seeded.

The available historical photos indicated that disposal locations within Site 2 were most likely active between 1942 and 1977. An open dump in the vicinity of Site 2 appeared in photos dated 1942 through 1950. The Site 2 features comprise an irregular-shaped area of about 650 feet by 200 feet, or 130,000 square feet.

Site 3

Site 3 is immediately southeast of Site 2 and was reportedly used from 1955 to 1965 as a burn pit for solvents, paints, roofing materials, and other unspecified chemicals. The pit was approximately 20 feet wide by 30 feet long by 10 feet deep and may have been constructed as a subsurface "cage." Residue from the pit was occasionally removed and deposited at an unknown area of the NAWC Warminster property. Upon closure, Site 3 was reportedly backfilled with on-base soil and regraded.

No evidence of a pit or open burning was identified from aerial photo analysis; however, disturbed ground and open storage were noticed in the area between 1958 and 1973. The available historical photos indicated that disposal locations within Site 3 were most likely active between 1955 and 1978. Upon closure, Site 3 was reportedly backfilled with on-site soil and regraded. Scrub brush was allowed to grow at the site. Surface water drainage from the site is toward the northeast into the unnamed tributary. The Site 3 features comprise an area of about 25,000 square feet.

Impoundment Area

The Navy formerly operated eight unlined impoundments or lagoons for storage of wastewater treatment plant sludges. These lagoons were located in the northern corner of Area A. Each lagoon had approximate dimensions of 60 feet wide by 75 feet long, with depths of approximately 8 to 10 feet. The lagoons were clean-closed in 1973, backfilled, and replaced with two concrete-lined surface impoundments. The area now consists of two inactive concrete lagoons and includes the location of an active groundwater treatment plant.

AREA A SOIL REMOVAL ACTIONS

During the construction of a groundwater treatment plant adjacent to and on top of the former Impoundment Area, elevated levels of metals were encountered. A removal action was conducted in 1996 to remove soils at two locations beneath the footprint of the treatment plant building and surrounding property.

In a separate action, based on preliminary RI results, about 6,700 tons of nonhazardous Area A surface and subsurface soils were excavated, transported, and disposed in an off-base landfill in 1998. A small amount (about 100 pounds) of flammable solids or corrosive liquids were also disposed. Soils were excavated from two separate locations within Site 1, three locations within Site 2, and one location near Site 3. The purpose of these actions was to address Site 1 subsurface soils and Site 2 and 3 surface soils primarily contaminated with levels of inorganics that presented unacceptable risks to human health and ecological receptors. The inorganics of concern included antimony, cadmium, chromium, lead, or thallium, depending on the specific site being addressed. For Site 1 subsurface soils, trichloroethene (TCE), one of the primary contaminants detected in Area A groundwater, was also identified as a compound of concern. Several polycyclic aromatic hydrocarbons (PAHs) were found to present unacceptable risks for Site 2 and 3 surface soils, including anthracene, benzo(a)pyrene, and benz(a) anthracene.

Removal clean-up goals were established for each contaminant based on the potential risks identified through the RI work. Additional sampling and analysis were performed until the removal clean-up goals were met for all soils of concern. The RI/FS report for OU-9 is based on conditions at Area A after the removal actions were conducted.

AREA A CHARACTERISTICS

Surface soils in the vicinity of Area A consist primarily of loam and silt loam deposits. Soil thicknesses from borings installed during the RI ranged from approximately 7 to 22 feet.

An unnamed tributary of Little Neshaminy Creek is located north of Area A. This stream originates from a stormwater culvert under Jacksonville Road and flows from the southeast to the northwest before turning north, away from the base. The current stormwater outfall (OF1) within Area A and along the base boundary may represent the original discharge point of a former stream on base property. The outfall lies between Sites 2 and 3. Other outfalls within Area A capture stormwater drainage from the parking lot south of the former guardhouse location.

A small forested wetland dominated by mature red maple and arrowwood was identified just north of the stream and beyond the base property boundary during a wetland assessment conducted as part of the Phase III RI work. This assessment concluded that the stream and wetlands appear fairly healthy and that the forested areas provide good wildlife habitat within an urbanized landscape. No evidence of pollution, fish kills, or stressed vegetation was observed. Urban trash and litter were common in the stream and were scattered throughout the floodplain. There are no known critical habitats of endangered species located within 1 mile of the Area A sites.

RI FIELD ACTIVITIES FOR AREA A

RI field activities were performed at Area A between 1989 and 1999. The field work focused on characterizing known and potential sources of contamination within Area A. The results of previous investigations and analysis of historical aerial photographs identified these sources. Field work included soil gas sampling, geophysical surveys, surface soil sampling and analysis, subsurface soil sampling and analysis, and a wetlands assessment. The subsurface studies consisted of drilling soil borings and excavating test pits to better determine the nature and extent of subsurface contamination. In addition, a surface water and sediment sampling and analysis program was conducted to evaluate the impacts of the base on the nearby stream.

Geophysical [i.e., electromagnetic (EM) conductivity] surveys were used to delineate the approximate boundaries of known and suspected sites. Soil gas surveys were employed in areas of suspected subsurface disposal of wastes containing volatile organic compounds (VOCs). The locations of the soil gas surveys took into consideration those potential sources identified from aerial photos, the EM survey, the results of previous investigations, and historical information regarding the locations of subsurface disposal sites. Coordinates of suspected historical disposal locations, provided by the Environmental Photographic Interpretation Center (EPIC), were used to focus the surveys along with any other available information.

Test pits and soil borings were used to characterize actual subsurface conditions at known or potential disposal sites. The locations of the test pits and soil borings were selected based on the results of the soil gas and geophysical surveys, as well as on aerial photo records, field observations, and previous field work findings. Subsurface soil/waste samples were obtained from the test pits/borings to characterize the encountered materials.

Surface soil/waste sampling was conducted in areas where surface disposal of wastes was a potential concern. In addition, a background soil sampling and analysis program was performed to provide a background database with which to compare potentially impacted soils results. Two rounds of surface water and sediment sampling and analysis were conducted to determine the nature and extent of contamination in

nearby streams. A wetlands assessment was also performed to provide a qualitative appraisal of the plants and animals associated with wetlands downstream of the base.

NATURE AND EXTENT OF CONTAMINATION FOR AREA A SITES

Site 1

The EM survey at Site 1 delineated an area with low conductivity approximately 70 feet southeast of the fence that borders the northwestern side of NAWC Warminster and about 60 to 100 feet south of the northwest to southeast fence. VOCs were detected in several soil gas samples near Site 1, including tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), carbon tetrachloride (CCl_4), and ethylbenzene. The subsurface investigation at Site 1 revealed an area of multi-colored silty clay, which may represent buried sludges that were relocated from the Impoundment Area. This area was about 0.25 acre in size; the depth of buried materials was estimated to range from 6 to 8 feet. Bedrock was encountered at Site 1 ranging from 6.5 to 16 feet below the ground. The area apparently had been extensively reworked and filled with waste and natural, clean soils used as backfill.

Before response actions were taken in 1998, a series of sampling investigations were conducted at Site 1 as part of the Phase II and Phase III RI work (including supporting supplemental investigations) to characterize the site and related environmental contamination. The pre-removal sample results were compared to state and federal risk-based screening concentrations for residential soil. Several surface soil samples contained organic compounds, including the dioxin OCDD, the furan 1,2,3,7,8-PECDD, Aroclor 1248, and Aroclor 1260 at levels above the screening criteria. VOCs were not found at elevated levels in surface soil. A risk assessment for Site 1 surface soil was completed using pre-removal data, and did not identify unacceptable risks for this soil.

Prior to the response actions, subsurface soils at Site 1 contained polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and metals. Benzo(a)pyrene and Aroclor 1260 were found in at least two samples at concentrations above the range of background soil levels and respective soil screening criteria. Several metals (e.g., antimony, cadmium, lead, manganese, and vanadium) were also detected at levels above representative background soil concentrations and applicable soil screening criteria. The samples from the former pit at Site 1 contained the highest metal concentrations. TCE was also detected above the soil screening level for the soil-to-groundwater migration pathway. The risk assessment for Site 1 subsurface soil using pre-removal data identified unacceptable carcinogenic risks compared to the target risk range (i.e., 1×10^{-4} to 1×10^{-6}).

In 1998, subsurface soils were excavated from two separate locations at Site 1 as part of removal action activities. The removal actions were conducted to address areas with elevated and unsafe contaminant

concentrations, as well as areas exhibiting evidence of actual or potential waste material. Remnants of several drums were also removed from the vicinity of Site 1. Samples were collected during and after the 1998 removal actions to verify that all removal clean-up goals for Site 1 subsurface soil were met.

Following the removal work, there were no exceedances of the soil screening criteria for Site 1 surface soils. Among the subsurface soil samples collected at locations outside the removal excavation locations, only arsenic was detected at levels that exceeded the maximum soil background concentration at the base and screening criteria. Arsenic was detected in two samples from the same soil boring location at levels ranging from 12.8 to 25.5 mg/kg. None of the substances targeted for the Site 1 removal action (TCE, antimony, cadmium, and chromium) were detected at concentrations above screening criteria.

Site 2

The EM survey over Site 2 delineated two possible anomalies. One anomaly was located beneath the entrance road southeast of the guardhouse in this area. The second anomaly was recorded along the northeastern edge of Site 2 . However, the anomalous EM readings may have been influenced by sources of cultural interference (e.g., stormwater piping and culverts) throughout much of this area.

An area of consistent positive soil gas readings was identified north of the fuel storage area in the vicinity of Site 2. The most frequently detected VOCs were PCE, TCE, CCl_4, and 1,1,1-trichloroethane (1,1,1-TCA). This area did not directly correspond to any EM anomaly or historical feature. Soil borings were drilled in the vicinity of all historical features within the vicinity of Site 2. These borings detected the presence of waste material, including fill, ash, charred debris, cinders, cables, wire, glass, ceramic fragments, wood, bricks, and scrap metal fragments. A majority of the waste material resembled construction or building demolition debris.

Before the 1998 response actions, several RI and supplemental soil investigations were performed at Site 2 to characterize the site and the degree of environmental contamination. The pre-removal surface soil results indicated that several metals exceeded soil screening concentrations in this area. The most frequent exceedances were for antimony, arsenic, copper, and lead, and a few PAHs and PCBs also exceeded screening concentrations in several samples. The elevated metals and PAHs were contained in samples located along the base fenceline, and between the fuel farm and the gravel access road to the north. A risk assessment for Site 2 surface soil was completed using pre-removal data, and identified unacceptable risks for this soil.

Semivolatile organics, pesticides, PCBs, and low levels of dioxins and furans were found in the pre-removal Site 2 subsurface soil samples. Several PAHs were detected in subsurface soil above soil screening levels. Aroclor 1254 and Aroclor 1260 were also found in samples at concentrations above the range of

background soil levels and respective soil screening criteria. Several metals were also detected in subsurface soil at levels above representative background soil concentrations, particularly in the eastern and southwestern portions of the site. However, only antimony, arsenic, lead, and vanadium were found above applicable soil screening criteria in more than two subsurface soil samples. The pre-removal risk assessment for Site 2 subsurface soil identified unacceptable risks for this soil.

Surface soils were excavated from three locations at Site 2 as part of removal action activities, while subsurface soils were removed from a portion of one location. The removal actions addressed areas with elevated and unsafe contaminant concentrations. Similar to Site 1, samples were taken to confirm that all soil removal clean-up goals for Site 2 were attained.

After the Site 2 removal actions, surface soil samples collected at a few locations outside the excavated areas contained concentrations that exceeded soil screening criteria and maximum soil background levels. The substance detected most often was benzo(a)pyrene. Lead was the only inorganic detected above the screening criteria in one sample. The benzo(a) pyrene and lead concentrations did not exceed removal clean-up goals established for Site 2 soils under industrial land use.

Among the post-removal subsurface soil results, benzo(a)pyrene, arsenic, and lead were detected above the screening criteria and maximum background concentrations. None of the removal clean-up goals for these substances regarding Site 2 subsurface soil were exceeded, except for one detection of lead in a steeply-sloping and inaccessible area.

Site 3

The Phase I EM survey showed an anomalous area about 30 feet by 40 feet in the vicinity of Site 3. The Phase III EM survey, however, did not identify any EM anomalies in this area. Interference from buried utilities hindered the ability to mark such anomalies, if present near Site 3.

The test pits and soil borings conducted at Site 3 indicated that waste material was present, including cinders, charred debris, glass pieces, metal scraps, ash, wood, metal, and brick fragments. The wide distribution of burned cinders found near Site 3 may represent the regraded contents of the burn pit and unburned portions of any debris disposed .

Prior to the response action at Site 3, several RI and supplemental soil investigations were carried out to characterize the site and the nature and extent of contamination. The pre-removal surface soil results indicated that several PAHs exceeded soil screening concentrations in this area. Several metals were detected at levels above representative background soil concentrations and soil screening criteria; however, only beryllium, lead, and vanadium were detected above screening criteria in more than one surface soil

sample. The pre-removal risk assessment for Site 3 surface soil identified unsafe risks due to the PAH levels.

The Site 3 results indicated that several PAHs, Aroclor 1254, and two inorganics were detected at levels exceeding screening criteria. The risk assessment for Site 3 subsurface soil did not identify any unsafe risks. Among the Site 3 subsurface soil results, benzo(a)pyrene was the compound most frequently detected. The PAH compounds may be related to the incomplete combustion of materials that are burned.

Surface soil was excavated from one location at Site 3 during the 1998 removal action. The removal action addressed elevated PAH concentrations. Samples were collected during and after the removal to verify that the soil removal clean-up goals for Site 3 were met.

Following the removal action at Site 3, there were no exceedances of the removal clean-up goals for surface soil. Benzo(a)pyrene was found at four sample locations at levels that exceeded screening criteria and the maximum soil background concentration; however, none of the levels were greater than the removal clean-up goal for this compound.

Impoundment Area

Several areas of positive soil gas readings were identified in the vicinity of the impoundments. Generally, VOC vapors were more frequently recorded beneath the existing concrete lagoons (i.e., IM4, IM5, and IM6) than from any other individual impoundment. The highest soil gas readings were from IM5, which was the closest impoundment to the former fuel storage area.

The soil borings drilled at the impoundments indicated that some minor waste material was present, including coal, brick fragments, roots, ash, crushed stone, concrete pieces, and cinders. The thickness of fill and waste material ranged between 0 and 10 feet below ground surface (bgs); the average thickness of non-native fill was about 0 to 3 feet bgs.

The soil boring results indicated that semivolatile organics, pesticides, and PCBs were generally not present in more than one subsurface soil sample from the Impoundment Area. Very low levels of VOCs (e.g., TCE and PCE) were detected. The most frequently detected metals among subsurface soil samples were beryllium, chromium, manganese, mercury, and silver; however, only manganese concentrations exceeded soil screening levels. Among the organic compounds, only benzo(a)pyrene was detected at concentrations above the screening criteria in more than one sample.

In 1996, subsurface soils were excavated from two separate locations at the impoundments as part of removal action activities. The removal actions were conducted to address areas with unsafe inorganic

contaminant concentrations. Following the removal work, there were no exceedances of the soil screening criteria for these inorganics at excavated locations, based on an industrial land use scenario.

Surface Water and Sediment

Low levels of VOCs, including TCE, PCE, carbon disulfide, and chloromethane, were detected in Area A surface water. Semivolatile organics, pesticides, and PCBs were generally not found, and if detected, the concentrations of these compounds did not exceed 1 ug/l in the surface water samples.

The surface water sample collected from inside outfall OF1 revealed that total metal concentrations for barium, copper, lead, manganese, and zinc were higher at this sample location than any other site-related surface water sample location. This suggests that water discharging through this outfall is contributing elevated chemical concentrations to the Area A stream. While known or potential sources within Area A may also be contributing to this contamination by possibly leaching soil contaminants to the stream or by overland runoff, these transport mechanisms are not believed to be as significant.

Several VOCs were found above background concentrations in Area A sediment samples. Sediment samples closest to OF1 had the most frequent VOC detections. The maximum TCE and PCE concentrations were detected in a sediment sample located about 250 feet away from the base and downstream from a small feeder stream to the unnamed tributary of Little Neshaminy Creek. Several pesticides, PCBs, and semivolatile organics were detected in Area A sediment samples. The most frequent chemical detections above background sediment levels were PCBs and PAHs. The highest PAH concentrations were found in the sediment sample from OF1. At this location, PAH levels ranged from 1,300J to 27,000J ug/kg.

The highest metal levels were from sample locations downstream of Area A. Samples collected along the stream between Jacksonville Road and OF1 generally showed lower metal concentrations compared to samples collected downstream of OF1. The analytes detected above background included beryllium, barium, chromium, copper, lead, mercury, selenium, silver, and zinc.

ASSESSMENT OF HUMAN HEALTH AND ECOLOGICAL RISKS

Both human health and ecological risk assessments were conducted to estimate the actual or potential risks to human health and the environment resulting from the presence of contamination in Area A media other than groundwater. For surface and subsurface soils, the evaluation was based on the nature and extent of contamination present at Area A after the 1996 and 1998 soil removal actions. A risk assessment was also performed to evaluate the actual or potential risks to human health and the environment due to the presence of contamination in surface water and sediment in the stream (an unnamed tributary of Little Neshaminy Creek) adjacent to the Area A sites.

The intended re-use for Area A is industrial, as designated in economic development conveyance (EDC) and public benefit conveyance plans by the FLRA and local municipal authorities. Both industrial and residential risks under respective land use scenarios were evaluated for the human health risk assessment. Residential risks were estimated as a baseline condition to determine if any land-use restrictions might be required for the Area A parcel.

Both carcinogenic and noncarcinogenic risks were assessed. In general, carcinogenic risks in the range of 10^{-4} to 10^{-6} are considered acceptable. Cumulative incremental cancer risks greater than 1×10^{-4} generally indicate that some degree of remediation is required, and cancer risks below 1×10^{-6} normally will not result in remedial efforts. A cancer risk of 1×10^{-6} indicates that the exposed receptor has a one in a million chance of developing cancer under the defined exposure scenario. Noncarcinogenic risk was assessed using the concept of hazard quotients (HQs) and hazard indices (HIs). HIs were generated by summing individual HQs for contaminants of potential concern. An HI exceeding unity (1.0) indicates that there may be potential noncarcinogenic health risks associated with exposure.

Human Health Risks for Soils

No estimated carcinogenic risks or noncarcinogenic risks above the target risk levels of 1×10^{-4} and 1.0, respectively, were present for the industrial land use scenario regarding Area A surface and subsurface soils. These are the highest risks identified under intended reuse of Area A property. These risks fell within the target risk range of 10^{-4} to 10^{-6} and therefore may be considered acceptable.

Both noncarcinogenic and carcinogenic risks above the target risk levels of 1.0 and 1×10^{-4}, respectively, were estimated for the hypothetical future residential child evaluated for contaminants of potential concern in surface soil and subsurface soil. Specifically, non-carcinogenic risks to residential children were identified in Site 2 and Site 3 surface soils and in subsurface soils associated with all four sites at Area A. Antimony, chromium, manganese, or silver contributed to the noncarcinogenic risk estimates. Carcinogenic risks were also estimated for subsurface soils at Site 3, primarily associated with

benzo(a)pyrene. The removal action was not intended to remove contaminants to a level protective of residential land use, as the intended re-use plans are expected to be industrial in nature.

For Site 2 surface and subsurface soils and Site 3 subsurface soil, lead was identified as a contaminant of potential concern. Blood-lead levels in hypothetical residential children were evaluated using the average lead concentration for these soils. The estimated percentages of residential children (ages 1 to 6) exposed to Site 2 surface and subsurface soils with blood-lead levels above 10 ug/dl were 0.26 percent and 0.73 percent, below the protective level of 5 percent. Therefore, lead levels in soils do not present an unacceptable risk at Site 2 to the future residential child.

The estimated percentage (6.42 percent) of hypothetical residential children exposed to subsurface soil at Site 3 with a blood-lead level above 10 ug/dl was above the protective level. However, the model also predicted a blood-lead level of 5.24 ug/dl for most children, which is below the protective level cutoff of 10ug/dl. Therefore, adverse effects to children are not expected from lead concentrations in Site 3 subsurface soil.

Human Health Risks for Surface Water and Sediment

Estimated cancer and noncancer risks for recreational children exposed to surface water via wading and to sediment via ingestion and dermal contract were not found to be significant (i.e., all cancer risks equal to or less than 1.0×10^{-6} ; all HIs less than 1.0) for nearby Area A surface water and sediment.

Ecological Risks

The presence of elevated PAH concentrations in sediment samples adjacent to Area A and elevated levels of metals in sediment samples adjacent and downstream of Area A suggests contaminant inputs in the stretch of the stream north of Sites 2 and 3. Potential ecological risks were estimated by comparing stream sediment sample analytical results to published conservative benchmarks established for sensitive receptors. Based on this assessment, the potential may exist for toxic effects to aquatic organisms and semi-aquatic receptors that feed on them. However, this stretch receives stormwater discharges and overland runoff from large paved parking areas at the base and Jacksonville Road. Additional sampling and analysis might be necessary to differentiate between potential sources of stream contamination other than Area A and to characterize any related impacts and potential risks to ecological receptors.

FEASIBILITY STUDY

Based on the RI results, a feasibility study (FS) was prepared for contaminated sediment associated with the adjacent Area A stream as well as contaminated soils associated with Area A. The soils of primary

concern were Site 2 surface soil and subsurface soils associated with Sites 1, 2, 3, and the Impoundment Area. The purpose of the FS was to develop and evaluate potential remedial alternatives for addressing potential risks to ecological receptors associated with the Area A stream. For Area A surface and subsurface soils, no unacceptable carcinogenic or noncarcinogenic risks were present above EPA's target risk levels of 1×10^{-4} and 1.0, respectively, for the industrial land use scenario. Industrial use is the reasonably anticipated future land use for Area A. While residential use is not anticipated, Area A soils were determined to present unacceptable non-carcinogenic risk under this specific land use.

To limit the reuse of Area A to industrial or commercial purposes, institutional controls should be implemented. As such, the FS evaluated institutional controls as a general response action for addressing Area A soils and to prevent the potential migration of soil contaminants to the nearby Area A stream. These controls are intended to protect ecological receptors associated with the Area A stream from adverse effects due to additional sediment contaminant loading.

For Area A sediment, remedial technologies and process options were evaluated and screened to select those that were most viable for the site conditions and contaminants. The technologies and process options that pass the screening process were combined to form remedial alternatives that will address site contamination. The remedial alternatives were then evaluated to distinguish positive and negative aspects of each alternative and then compared to one another.

REMEDIAL ACTION OBJECTIVES

Based on the environmental media of concern and the potential receptors/pathways of exposure, remedial action objectives were established for Area A sediment and soils:

- Mitigate the potential risks to ecological receptors from Area A sediment contamination.
- Prevent the migration of Area A soil contaminants to nearby surface water and sediment.
- Restrict residential land use in the vicinity of Area A to protect human health.

DEVELOPMENT OF REMEDIAL ALTERNATIVES

Based on the nature and extent of Area A soil and sediment contamination, estimated ecological risks, current site conditions, completed removal actions, remedial action objectives, and general response actions, technologies and process options were identified. For Area A sediment, the following response actions were considered:

- Environmental monitoring
- Containment (i.e., surface water controls)

- Removal (e.g., dredging) of contaminated sediment, treatment, and off-base disposal

For Area A soils, the no-action and institutional control general response actions were evaluated to meet applicable remedial action objectives. The general response actions, technologies, and process actions were screened for effectiveness, implementability, and cost. In addition, the no action alternative was retained as a baseline alternative.

Two of the general response actions for Area A sediment did not pass the screening process. More specifically, containment (e.g., sediment traps and stream diversion measures) was not retained due to implementability concerns. Erosion control measures have already been implemented at Site 2 to minimize the surface runoff of water and suspended materials (such as soils) to the nearby stream. These controls consist of a concrete berm and riprap to increase the infiltration of rainfall and surface runoff into the ground, and to divert any remaining runoff to a specific location. The construction of additional surface water controls would be complex due to the small size of the stream itself, the relatively steep embankments along both sides of the stream, and difficulty in accessing the stream due to mature vegetation and the slopes themselves.

The removal, treatment, and off-base disposal alternative was also eliminated due to effectiveness and implementability concerns. The small size of the stream, the limited amount of significant sediment deposits, and the potential to dewater dredged materials and revegetate any damaged wetlands, limits the ability to adequately perform this type of remedial alternative.

The alternatives that passed the screening process are briefly described below.

Alternative 1: No Action: Under this alternative, no action would be undertaken to protect ecological receptors, address sediment contamination in the stream, or mitigate the migration/release of soil contaminants into the nearby stream.

Alternative 2: Institutional Controls and Environmental Monitoring: This alternative relies on institutional controls to restrict construction and other excavation activities that might disturb Area A soils in a manner that results in migration of Area A soil contaminants to the stream. Also, while residential land use is not reasonably anticipated for Area A, land use restrictions would preclude residential land use in the vicinity of Area A through deed restrictions, covenants, or zoning ordinances. The institutional controls would also be implemented to prevent human exposure to soil contaminants at Area A.

As part of Alternative 2, surface water, sediment, and biological samples (e.g., benthic macroinvertebrates) would be sampled on a periodic basis to monitor the level of contaminants and potential adverse stream effects over time. The monitoring program would help determine the cause of any actual or potential

impacts to the stream and related ecological receptors. If necessary, modifications to the monitoring program would be made to further define or quantify the extent of these impacts and to identify any possible causes of the contamination.

EVALUATION OF ALTERNATIVES

The purpose of the comparative evaluation of alternatives was to identify and positive and negative advantages of each alternative to support the remedy selection process. Since no action would be taken under Alternative 1, it would not comply with the pertinent evaluation criteria and would not be effective. Alternative 1 is not protective of the environment since the potential for contaminants in sediment to pose risks to these receptors would continue to exist. Action would not be taken to meet the remedial action objectives for Area A soils.

Alternative 2 would limit the migration of soil contaminants to surface water and sediment via institutional controls. This alternative provides long-term monitoring to evaluate stream conditions and potential ecological risks in the event that these conditions and risks significantly change over time. If necessary, modifications to the monitoring program would be made to further define or quantify any actual impacts to the stream.

Alternative 2 is protective of human health by limiting the potential for exposure to soil contaminants through land use restrictions. Deed restrictions are an effective option for prohibiting certain types of land uses since these restrictions are inherently part of the property transfer process, regardless of the status of ownership. This alternative does not reduce the toxicity, mobility, or volume of existing sediment contaminants. However, the technologies to address this contamination are not easily implementable and may not be effective in the long-term, given current stream conditions.

As part of Alternative 2, the environmental monitoring program would be effective over the short-term to ensure that sediments are not adversely impacted by either sources of hazardous substance contamination or by urban runoff from Sites 2 and 3. Institutional controls are also effective on both a short- and long-term bases. Alternative 2 is readily implementable within an estimated period of 6 months.

There are no costs associated with Alternative 1. The present-worth costs of Alternative 2 are $275,360. More than half of the Alternative 2 costs would be incurred within the first year of implementation.

1.0 INTRODUCTION

In response to Contract Task Order No. 290 under Contract N62472-90-D-1298, Tetra Tech NUS, Inc. (TtNUS) is submitting this remedial investigation (RI) report and feasibility study (FS) for Operable Unit 9 (OU-9) (Area A media other than groundwater) at the former Naval Air Warfare Center (NAWC) (formerly the Naval Air Development Center), Warminster, Pennsylvania. This work is part of the Navy's Installation Restoration Program (IRP), which is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures, as needed.

IRP activities are typically performed in four distinct phases. The first phase consists of a preliminary assessment (PA). Phase II involves a site inspection (SI). The third phase is a remedial investigation and feasibility study (RI/FS), which are intended to characterize physical and chemical parameters and risks associated with the facility. The last phase consists of remedial actions designed to control and mitigate contamination. This report is prepared under Phase III IRP activities.

1.1 PURPOSE OF THE REPORT

Section 300.430 (a)(1)(ii)(A) of the National Oil and Hazardous Substances Pollution Contingency Act (NCP) provides that hazardous substance facilities should generally be remediated in operable units when early actions are necessary or appropriate to achieve a significant and accelerated risk reduction, when phased analysis or response is necessary or appropriate given the size or complexity of the site, or to expedite the completion of a total cleanup. Several operable units at NAWC Warminster have been identified to facilitate these objectives. OU-9, the subject of this report, comprises Area A media other than groundwater.

The purpose of this report is to describe investigation results for Area A soils and the stream north of the site, draw conclusions based on these results, and recommend any additional actions. In 1998, the Navy removed certain contaminated soils from portions of Area A based on the results obtained from the initial RI investigations. This report describes investigation results prior to the removal actions and the current nature and extent of contamination remaining after the removal work. Data from samples collected in areas that remained in place after the removal work are included in the human health risk assessment that is part of this report.

The main focus of the RI was to characterize soils and wastes in potential source areas at Area A, particularly suspected sources that were not addressed under the base-wide Environmental Baseline Survey (EBS). The RI also investigated nearby surface waters and sediments potentially impacted by Area A sites. Groundwater impacts associated with this area have previously been reported and are being

addressed as Operable Unit 1 (OU-1) (HNUS, 1993b and 1993c). Therefore, groundwater within Area A is not addressed by this report.

1.2 FACILITY BACKGROUND AND HISTORY

This section describes NAWC Warminster and provides a brief synopsis of the facility's background and history. More detailed discussion is provided in the RI work plans for the facility, available as part of the Administrative Record.

1.2.1 Facility Description

NAWC Warminster is located in the township of Warminster, Bucks County, Pennsylvania. The facility can be found on the United States Geologic Survey (USGS) Hatboro 7.5-minute topographic quadrangle map, a portion of which is reproduced as Figure 1-1. The total area of NAWC Warminster is approximately 734 acres. The facility lies in a populated suburban area surrounded by private homes, various commercial/industrial businesses, and a golf course. On-base areas include various buildings and other complexes connected by paved roads, the runway and ramp area, mowed fields, and a small wooded area.

The facility is located on a ridge, generally oriented east-west, with elevations ranging from 297 feet at the northwestern property boundary to 377 feet at the eastern boundary. Slopes are gentle and average three to five percent. The northern portion of the facility (about 65 percent) drains into small, unnamed tributaries of Little Neshaminy Creek. The remaining portion drains into unnamed tributaries of Pennypack Creek.

The main areas of investigation at NAWC Warminster include several waste sites covering more than 15 acres. All sites are located within the NAWC Warminster property and include the following:

- Three waste burn and disposal pits (Sites 1, 3, and 6)
- Two sludge disposal pit areas (Sites 2 and 7)
- Two landfills located on the north and south sides of the active runway (Sites 4 and 5)
- One fire training area (Site 8)
- A series of eight unlined impoundments (Impoundment Area)

These sites, along with other suspected sources at the base, have been grouped into four general areas based on geographic location (i.e., their proximity to one another), similarities regarding source and waste characteristics (i.e., methods of waste disposal and types of wastes deposited), and their common effects on nearby receptors (e.g., aquifers, surface water bodies, and human populations) (Figure 1-2). The general areas are:

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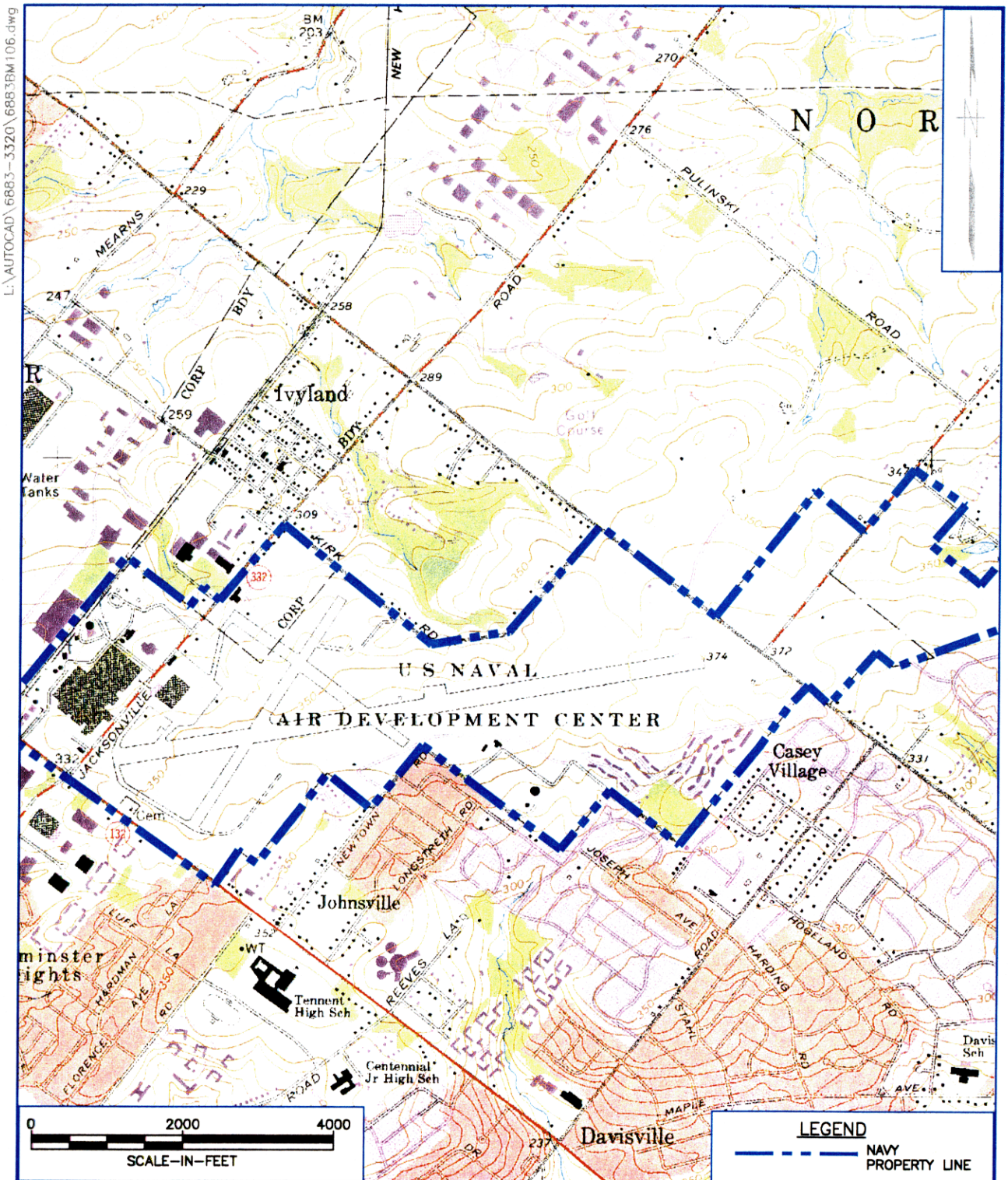
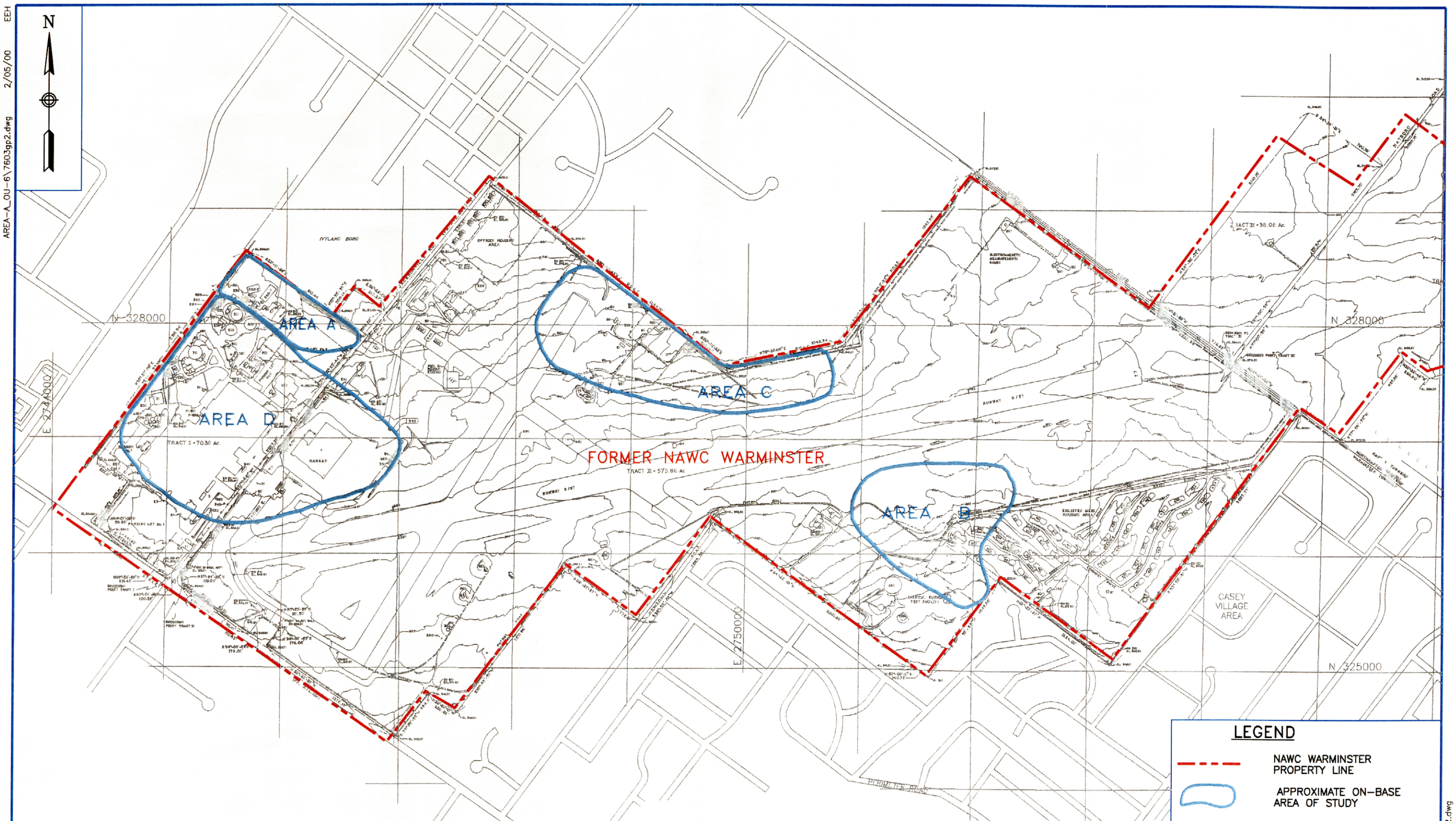


DRAWN BY ASM/LDL DATE 4/8/99	Tetra Tech NUS Inc.	CONTRACT NO. N62472-90-D-1298	OWNER NO. CTO 0159
CHECKED BY DATE	SITE LOCATION MAP	APPROVED BY Garth Glenn DATE 6/24/99	
COST/SCHED-AREA	FORMER NAWC WARMINSTER	APPROVED BY DATE	
SCALE 1"=2000'	WARMINSTER, PENNSYLVANIA	DRAWING NO. FIGURE 1-1	REV. 1

SOURCE: (7.5 MINUTE SERIES) U.S.G.S. HATBORO, PA QUADRANGLE

REV. 0 - 11/18/98 ASM

AREA-A_OU-6\7603gp2.dwg 2/05/00 EEH



DRAWN BY LDL	DATE 2/8/00	Tetra Tech NUS, Inc.	ON – BASE AREAS OF INVESTIGATION FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
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SCALE AS NOTED			

CONTRACT NO. 5838	
OWNER NO. 8120	
APPROVED BY	DATE
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442 ADV

- Area A - located in the northwestern corner of the base (Sites 1, 2, 3 and the Impoundment Area)
- Area B - located south of the main runway (Sites 5, 6, and 7)
- Area C - located north of the main runway (Sites 4 and 8)
- Area D - consisting of the main building complex at the base

Historically, wastes were generated during aircraft maintenance and repair, pest control, firefighting training, machine and plating shop operations, spray painting, and various materials research and testing activities in laboratories. These wastes included paints, solvents, sludges from industrial wastewater treatment, and waste oils. None of the sites are currently used for waste disposal.

The longest runway, which is inactive, is generally located along the topographically highest area at the facility. Many of the primary facility buildings are located west of the airstrip, along Jacksonville Road. A housing development for military enlisted personnel is within the southeastern portion of NAWC Warminster. A wastewater treatment plant is located in the northwestern corner of the facility.

Approximately 100 employees currently work at the former base, and 1,000 people reside at the enlisted personnel's housing area year round. The residents living at the enlisted housing area are the nearest population center; however, most work at a nearby Navy base in Willow Grove, Pennsylvania. The closest off-base home is about 200 feet away.

NAWC Warminster is underlain by the Stockton Formation, which provides water for more than 100,000 people within the area. Local surface water bodies are used for recreation and industrial purposes.

1.2.2 Facility History

The facility was originally the location of Brewster Aeronautical Corporation, a manufacturer of military aircraft. In 1944, the Navy assumed full control of the Brewster plant. The Naval Air Modification Unit was installed at the base to add design modifications to military aircraft produced at other locations. After World War II, activities at the base were altered; in 1949, the facility was designated the Naval Air Development Center (NADC), and its main mission, research, development, testing, and evaluation for Naval aircraft systems, was established. NAWC Warminster also conducted studies in anti-submarine warfare systems and software development. The facility name was changed from NADC to NAWC, Aircraft Division, on January 1, 1992. In 1996, NAWC Warminster was realigned under the Base Realignment and Closure (BRAC) Program managed by the Department of Defense (DOD). This realignment, which is due to the downsizing of the entire DOD budget, was implemented in September 1997. The realignment resulted in the relocation of NAWC Warminster activities to Naval Air Station (NAS) Patuxent River, Maryland. The base is

now closed and is being redeveloped for non-military use by the Bucks County Federal Lands Reuse Authority (FLRA).

The U.S. Environmental Protection Agency (EPA) officially recognized the NAWC Warminster sites as possibly needing investigation in September 1979. In November 1979, EPA completed a PA. In 1980, the Department of the Navy began its environmental investigative work at NAWC Warminster. The first study, known as the Clay/Law Report, inventoried disposal activities at each of the eight sites. Since 1980, a variety of environmental consultants under Navy contracts have studied these sites. The first of the resulting reports, prepared by JRB Associates in 1983, concluded that on-base contamination existed but probably was not affecting off-base water supply wells.

In 1985, EPA completed a PA/SI Report. In 1986, NAWC Warminster was proposed for inclusion on the National Priorities List (NPL) based on a Hazard Ranking System (HRS) score greater than 28.50. EPA used the HRS to assess the relative threat from releases of hazardous substances from the eight NAWC Warminster sites to surrounding groundwater and surface water. The facility score was based on the likelihood that a hazardous substance would be released from the sites, the toxicity and amount of hazardous substances at the sites, and the people and sensitive environments potentially affected by contamination at the sites.

On October 4, 1989, NAWC Warminster was placed on the final NPL. That same year, EPA submitted a draft Interagency Agreement to the Navy for formalizing and scheduling remedial activities. The contents of this agreement were negotiated in 1990. In 1991, TtNUS (formerly Halliburton NUS Corporation, then Brown & Root Environmental) was tasked to complete RI/FS activities at the facility.

1.2.3 Environmental Investigations

Since 1979, NAWC Warminster, regulatory agencies, and others have been involved in various regional environmental response actions for the study area. Some regional actions have been specific investigations of the NAWC Warminster sites. A number of wells within Warminster Township and other nearby townships have been sampled for volatile organic compounds (VOCs), and contamination by VOCs has made some groundwater unsuitable for potable use.

Since 1989, several RIs and FSs have been conducted at NAWC Warminster for the various areas of concern (i.e., Area A, Area B, Area C, and Area D). The Phase I RI was performed between October 1989 and April 1991 by SMC Environmental Services Group (SMC Martin, 1991). Phase II was performed between May 1992 and April 1993 (HNUS, 1992, 1993a). In October 1993, focused RI/FS work for groundwater contamination attributable to the base began and is continuing (HNUS, 1994a). Phase III,

which addressed potential source areas and their impacts to soils, surface waters, and sediments, began in January 1995 and was completed in October 1999.

Area D (with the exception of groundwater) was evaluated separately from other RI work. Except for Phase I, all other investigations have been conducted by TtNUS. A Technical Review Committee (later a Restoration Advisory Board (RAB)), which consists of representatives of the Navy, EPA, the Pennsylvania Department of Environmental Protection (PADEP), the Bucks County Health Department, the Northampton Township Municipal Authority, the Warminster Township Municipal Authority, and Upper Southampton Township, assisted in the planning and review of these activities

The following sections briefly summarize the status of investigations and response actions for each of the four areas of concern at the Warminster facility (see Figure 1-2).

1.2.3.1 Area A Investigations and Response Actions

Investigations

- Phase I (1989 - 1991): RI activities involved mapping VOCs in soil gas and detecting magnetic and conductive anomalies through electromagnetic surveys. Approximate site boundaries were identified and confirmation of site contamination was made through soil borings, installation of overburden and shallow bedrock monitoring wells, and groundwater sampling and analysis. Other media (surface water and sediment) were also sampled and tested. Test pits were excavated, local wells were inventoried, and a fracture-trace analysis was conducted. A biological characterization of a nearby stream was also done (SMC Martin, 1991).

- Phase II (1992 - 1993): RI/FS work helped determine the nature and extent of groundwater contamination, evaluate shallow groundwater flow and add to the hydrogeologic database, and ascertain possible remedial alternatives. Activities included installing additional overburden and shallow bedrock monitoring wells, sampling and analyzing groundwater, surface water, sediment, and soils, and evaluating aquifer characteristics through water-level monitoring and a pumping test. Groundwater-related RI and FS reports for OU-1 were released in April 1993 (HNUS, 1992, 1993a, and 1993b).

- Focused RI/FS for Groundwater (1993): This activity investigated groundwater conditions within and downgradient of Area A, as well as in other areas of the base. Monitoring wells were installed and water samples were collected for analysis. A water-level study and a more comprehensive aquifer pump test were also performed (HNUS, 1995e). A final RI report for Area A groundwater is now being prepared.

- Phase III (1995 - 1999): The primary RI objective was to characterize sources of contamination, primarily soils and wastes, at known and potential waste disposal sites. RI work included a soil gas survey, multiple surface geophysical surveys, test pits and soil borings, along with soil and waste sampling and analysis. A surface water and sediment sampling and analysis program was performed to evaluate the impacts of Area A on the nearby stream. An assessment of wetlands near Area A was also conducted (HNUS, 1994d; B&R Environmental, 1996a).

Response Actions

- Operable Unit 1 (OU-1): At the end of Phase II, the Navy and EPA selected an interim remedy for contaminated shallow groundwater attributable to Area A at the base, referred to as OU-1. The OU-1 Record of Decision (ROD) was signed in September 1993. The interim remedy which included installing extraction wells and building a treatment system, was constructed by July 1999. A final ROD for OU-1 will be prepared later this year.

- During the construction of the OU-1 remedy, the Navy excavated contaminated soils that were beneath the footprint of the treatment plant building or along the route of groundwater transfer piping near Area A. The soils were disposed in an off-base landfill. This work was performed in 1996.

- Using Navy funds, one commercial property with a contaminated well was connected to the Warminster Municipal Authority system in the summer of 1995. This property was located north of Site 2, at Area A.

- OU-9: Based on the Phase III RI, including the results of several supplemental investigations, the Navy excavated and disposed of contaminated soils and wastes from several locations within Sites 1, 2, and 3 between August 1998 and January 1999. An Action Memorandum for the Area A soil removal action was signed by the Navy in June 1998. OU-9 is the subject of this report.

1.2.3.2 Area B Investigations and Response Actions

Investigations

- Phase I (1989 - 1991): Activities were similar in scope to Area A. An air sampling program was also performed to evaluate the potential for atmospheric contamination in nearby residences (SMC Martin, 1991).

- Phase II (1992 - 1993): RI/FS work was similar to Area A. Several off-base well samples were also collected for analysis. Groundwater-related RI and FS reports for OU-1 were prepared in April 1993 (HNUS, 1992, 1993a, and 1993b).

- Focused RI for Groundwater (1993 - 1995): This work investigated groundwater conditions within and downgradient of Sites 5, 6, and 7. The focused groundwater scope of work was similar to Area A. Based on this work, a final RI report for Area B groundwater is scheduled to be released in March 2000.

- Phase III (1995 - 1999): The Phase III RI objective was to characterize sources of contamination, primarily soils and wastes at known and potential waste disposal sites. RI work was similar to that conducted for Area A (B&R Environmental, 1996a). Additional investigations for Sites 6 and 7 were performed in 1996 and 1997 to support limited removal actions for these sites. Following the removal actions, RI and FS reports for Sites 6 and 7 were prepared (TtNUS, 1999g and 1999h). A supplemental soil investigation was conducted for Site 5 in December 1999, and the Site 5 RI/FS report is now being prepared.

Response Actions

- OU-1: At the end of Phase II, the OU-1 ROD was signed to implement an interim remedy for contaminated shallow groundwater attributable to Area B. Extraction wells were installed in December 1994; however, the groundwater sample results indicated the general absence of significant contamination. The interim remedy is currently being re-evaluated.

- OU-2: Following Phase II, the Navy performed sampling of off-base drinking water wells in the vicinity of NAWC Warminster. Results from well water samples collected during the testing indicated that, at several residences, the groundwater had levels of VOCs greater than EPA's Maximum Contaminant Levels (MCLs). Beginning in April 1993, the Navy installed water treatment systems at these residences despite the lack of clear evidence that the Navy was responsible for all the elevated contaminant levels of concern. In the summer of 1994, EPA and the Navy connected homes in the Casey Village Area (located south of Sites 5, 6, and 7) to the Warminster Municipal Authority and Upper Southampton Water and Sewer Authority systems.

- OU-7: Based on the Phase III RI findings, including the results of several supplemental investigations, the Navy excavated and disposed of contaminated soils and wastes from several locations within Sites 6 and 7 in 1997. The ROD for OU-7 is scheduled to be signed by June 2000.

1.2.3.3 Area C Investigations and Response Actions

Investigations

- Phase I (1989 - 1991): Activities were similar in scope to Area A (SMC Martin, 1991).

- Phase II (1992 - 1993): RI/FS work was similar to Areas A and B. One off-base well sample was tested (HNUS, 1992).

- Focused RI for Groundwater (1993 - 1994): Groundwater conditions were investigated within and downgradient of Sites 4 and 8. The focused groundwater scope of work was similar to Areas A and B. Based on this work, separate RI and FS reports were submitted for Area C groundwater in August 1994 (HNUS, 1994b and 1994c). A schematic design for shallow groundwater remediation was completed in July 1994.

- Phase III (1995 - 1999): The Phase III RI objectives and field work were similar to those conducted for Areas A and B. A maintenance area and septic system drain field, both located between Site 4 and Site 8, were also investigated within Area C (B&R Environmental, 1996a TtNUS, 1999d and 2000a). An engineering evaluation/cost analysis (EE/CA) report was prepared to help support a removal action for Site 4 in July 1995 (HNUS, 1995d). A supplemental study for Site 8 was conducted between July 1998 and March 1999 to complete RI work for this site.

Response Actions

- OU-2: Following Phase II, the Navy performed sampling of off-base drinking water wells in the vicinity of Area C. In 1994, EPA and the Navy connected homes along Kirk Road to the Warminster Municipal Authority system.

- OU-3: The interim OU-1 remedy for Areas A and B was modified to incorporate the additional volume of contaminated groundwater associated with OU-3. The ROD for OU-3 was signed in March 1995. Construction of the groundwater treatment plant was completed in May 1996. Six extraction wells were installed in Area C, and piping and electrical wiring were run between these wells and the treatment plant. The system began full operation in July 1996.

- OU-5: Based on the Phase III RI findings, including the results of several supplemental investigations, the Navy excavated and disposed of contaminated surface soils along the western edge of the Site 8 runway extension in February 1999. The Action Memorandum for the Site 8 removal action was also signed in February 1999 (U.S. Navy, 1999a). The ROD for OU-5 (Site 8 media other than groundwater) was signed in September 1999 (U.S. Navy, 1999b).

- OU-6: The Action Memorandum for the Site 4 removal action was signed in June 1996. Based on the Phase III RI and EE/CA findings, the Navy excavated and disposed of contaminated soils and wastes from eight buried trenches at Site 4 in the fall of 1996. All work was completed in July 1997. The ROD for OU-6 (Site 4 media other than groundwater) is scheduled to be signed by May 2000.

1.2.3.4 Area D Investigations and Response Actions

Investigations

- Focused RI for Groundwater (1993 - 1996): Groundwater conditions were investigated within and downgradient of Area D. The focused RI groundwater scope of work was similar to the investigations for Areas A, B, and C. Based on this work, separate interim RI and FS reports were submitted for Area D groundwater in October 1996 (B&R Environmental, 1996c and 1996d). Final RI and FS reports are now being prepared.

- Area D RI (1996 - 1998): The Area D RI objective was to characterize sources of contamination, primarily soils and wastes at potential waste disposal sites within the main building complex at the base, including the hangar area east of Jacksonville Road. RI work included a soil gas survey, soil borings, and soil sampling and analysis. The RI report for Area D media other than groundwater was released in September 1998 (TtNUS, 1998). Based on the Area D RI results for media other than groundwater, an FS report was not warranted.

Response Actions

- OU-4: At the end of the focused groundwater RI for Area D groundwater, an interim ROD for OU-4 was released in September 1997. The interim remedy included installing extraction wells and connecting these wells to the existing groundwater treatment system and was completed by July 1999. A final ROD for OU-4 will be prepared later this year.

- OU-8: To date, no CERCLA response actions for specific Area D sources have been conducted. However, the Navy has removed several petroleum-related aboveground and underground storage tanks (USTs) within Area D and other areas at the base. The ROD for OU-8 (Area D Soils) is scheduled to be signed by June 2000.

The results and findings of all previous investigations are maintained in two local information repositories that contain the Administrative Record for NAWC Warminster. One repository is located at the base; the second can be found at the Bucks County Library, Doylestown Branch.

1.3 AREA A SITE DESCRIPTION AND HISTORY

Area A is located in the northwestern corner of NAWC Warminster, between Jacksonville Road and the railroad tracks located west of the base, and generally north of the wastewater treatment plant, fuel farm

area, and Parking Lot No. 2. Area A consists of several discrete disposal sites, Site 1, Site 2, Site 3 and the former Impoundment Area, which have been combined into one general study area for purposes of this report. Figure 1-3 shows the location of each site investigated within Area A. All sites are within the fenced NAWC Warminster perimeter and are found in the northwestern corner of the facility bordering an industrial, commercial area. Groundwater flow and surface water runoff are to the north for all sites.

A description of the known or potential sites within Area A and a summary of previous investigations for this area are provided in the following sections.

1.3.1 Site 1 Description

Site 1 is located on a portion of the NAWC Warminster property lying northwest of Jacksonville Road; the site is adjacent to the wastewater treatment plant (Figure 1-3). Site 1 is within 1,000 feet of an off-base food processing facility and within 300 feet of an unnamed tributary of Little Neshaminy Creek.

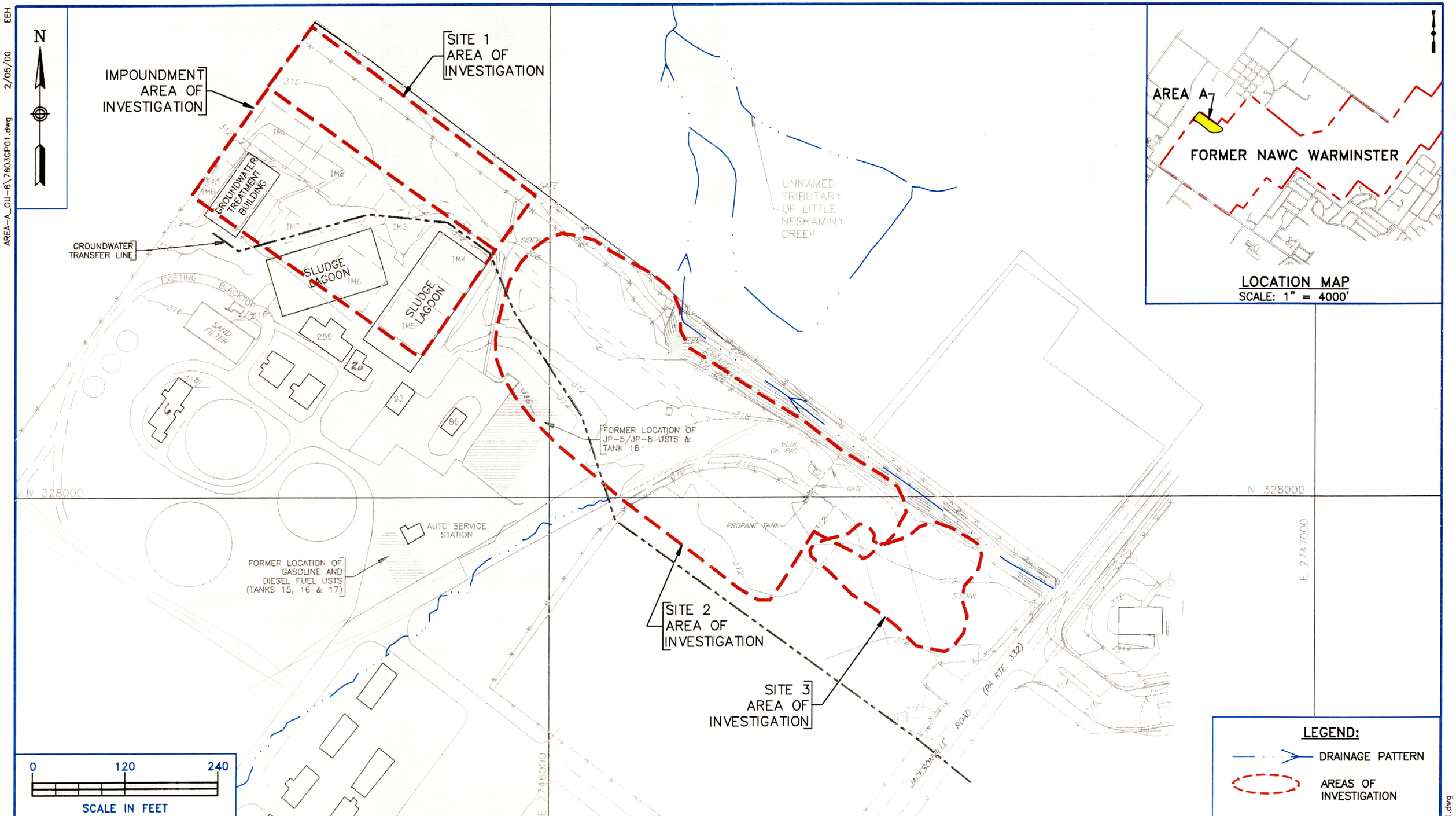
1.3.2 Site 1 History

The Navy initially reported Site 1 as a disposal site in the Navy Shore Activity Disposal Fact Form (U.S. Navy, 1980) and Notification of Hazardous Waste Sites (U.S. Navy, 1981). The site reportedly operated as a burn pit from 1940 to 1955 and was located at the embankment of a ravine formed by erosion action. Reportedly, the waste materials were dumped over the bank and burned. The materials included paint, oil, asphalt, roofing material, solvents, scrap metal, unspecified chemicals, and waste from one or more firing ranges.

The Navy also reported that Site 1 was used as a disposal site for excess soil from the grading for the extension of the main runway at the base. The quantity of wastes deposited or burned was unknown. After use of Site 1 was discontinued, the area was covered with soil from an on-base source.

Additional site background and historical information were provided by an Aerial Photographic Site Analysis Report for the base (EPIC, 1994). This report evaluated aerial photographs from March 1938 through March 1990 and identified several features within Site 1 that suggested possible or probable disposal pits and other miscellaneous features. These features are shown in Figure 1-4. Figures 1-5 through 1-11 are copies of aerial photos used in the historical review. The following information from the site analysis report is pertinent to this report.

The historical aerial photos indicate that at least two areas in the vicinity of Site 1 may have received fill material. In photographs from May 1948 and October 1950 (Figure 1-5), a vegetated, irregularly shaped pit or impoundment (P1) was identified adjacent to several other impoundments. The pit was approximately 100 feet by 35 feet in size. Photography from September 1958 revealed that the pit had been filled in and



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/20/00	OHM TRAILER AREA REMOVED, FORMER TANK LOCATIONS AND GROUNDWATER TRANSFER LINE ADDED.	LDL/EEH			

DRAWN BY EEH/LDL DATE 2/8/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

AREA A LAYOUT

FORMER NAWC WARMINSTER

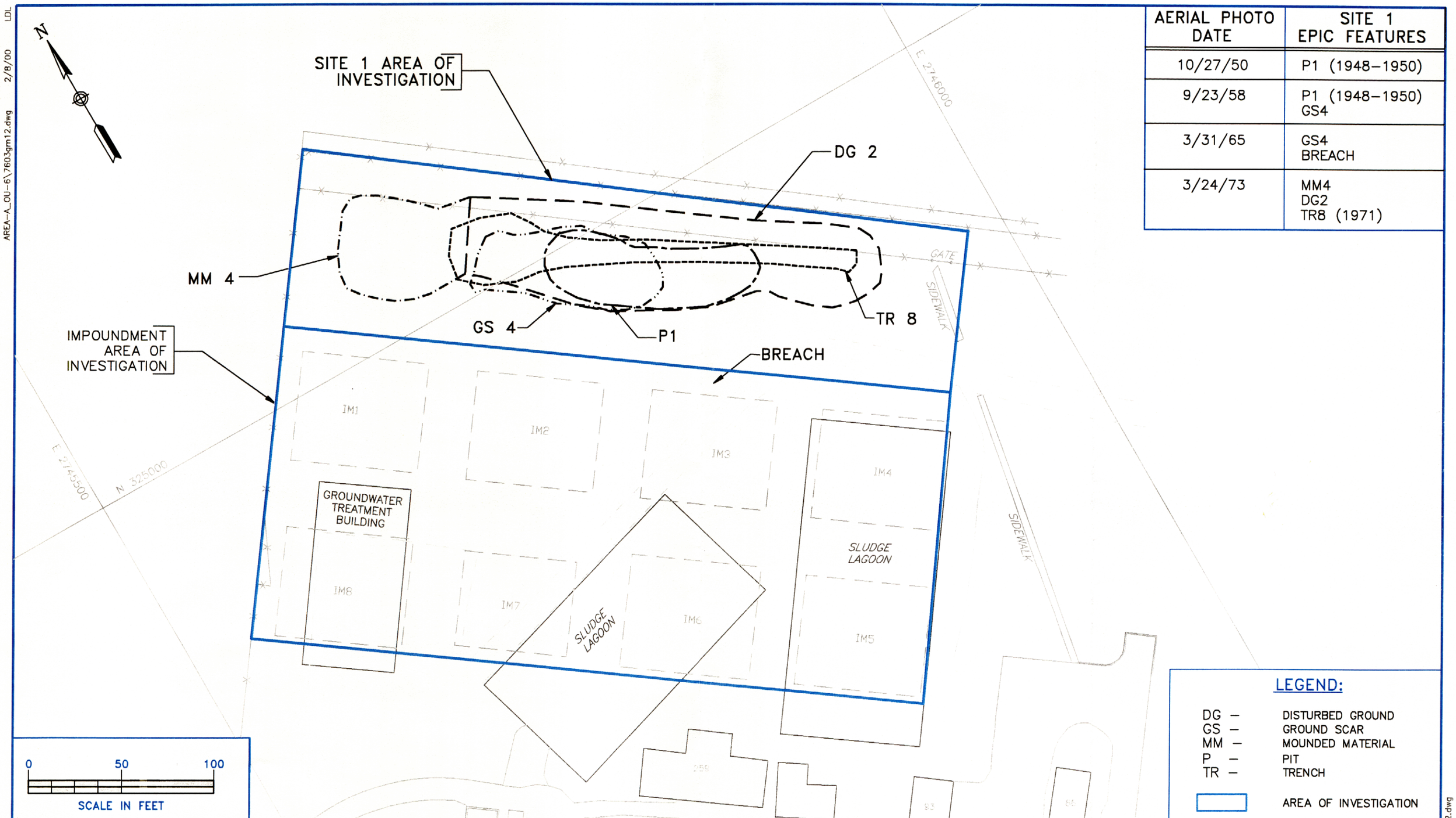
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY DATE 4/10/00
DRAWING NO. FIGURE 1-3
REV. 1

AREA-A_OU-6\7603GF01.dwg 2/05/00 EEH

AREA-A_OU-6\7603GP01.dwg

AERIAL PHOTO DATE	SITE 1 EPIC FEATURES
10/27/50	P1 (1948–1950)
9/23/58	P1 (1948–1950) GS4
3/31/65	GS4 BREACH
3/24/73	MM4 DG2 TR8 (1971)



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	OHM TRAILER AREA REMOVED.	LDL			

DRAWN BY LDL DATE 2/8/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

SITE 1 & IMPOUNDMENT AREA
EPIC FEATURES
FORMER NAWC WARMINSTER
WARMINSTER, PA

CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY DATE
DRAWING NO. FIGURE 1-4
REV. 1

LDL 2/8/00 AREA-A_OU-6\7603gm12.dwg

AREA-A_OU-6\7603gm12.dwg

FIGURE 1-5
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
OCTOBER 1950

Source: Aerial Photographic Site Analysis, Naval Air Development Center, Warminster, Pennsylvania. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, NV. TS-PIC-93053, May 1994 (not to scale).

FIGURE 1-6
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
SEPTEMBER 23, 1958

Source: Aerial Photographic Site Analysis, Nav Air Development Center, Warminste Pennsylvania. Environmental Monitoring Systen Laboratory, U.S. Environmental Protectic Agency, Las Vegas, NV. TS-PIC-93053, M 1994 (not to scale).

FIGURE 1-7
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
MARCH 31, 1965

Source: Aerial Photographic Site Analysis, Nav Air Development Center, Warminste Pennsylvania. Environmental Monitoring Systen Laboratory, U.S. Environmental Protectic Agency, Las Vegas, NV. TS-PIC-93053, Ma 1994 (not to scale).

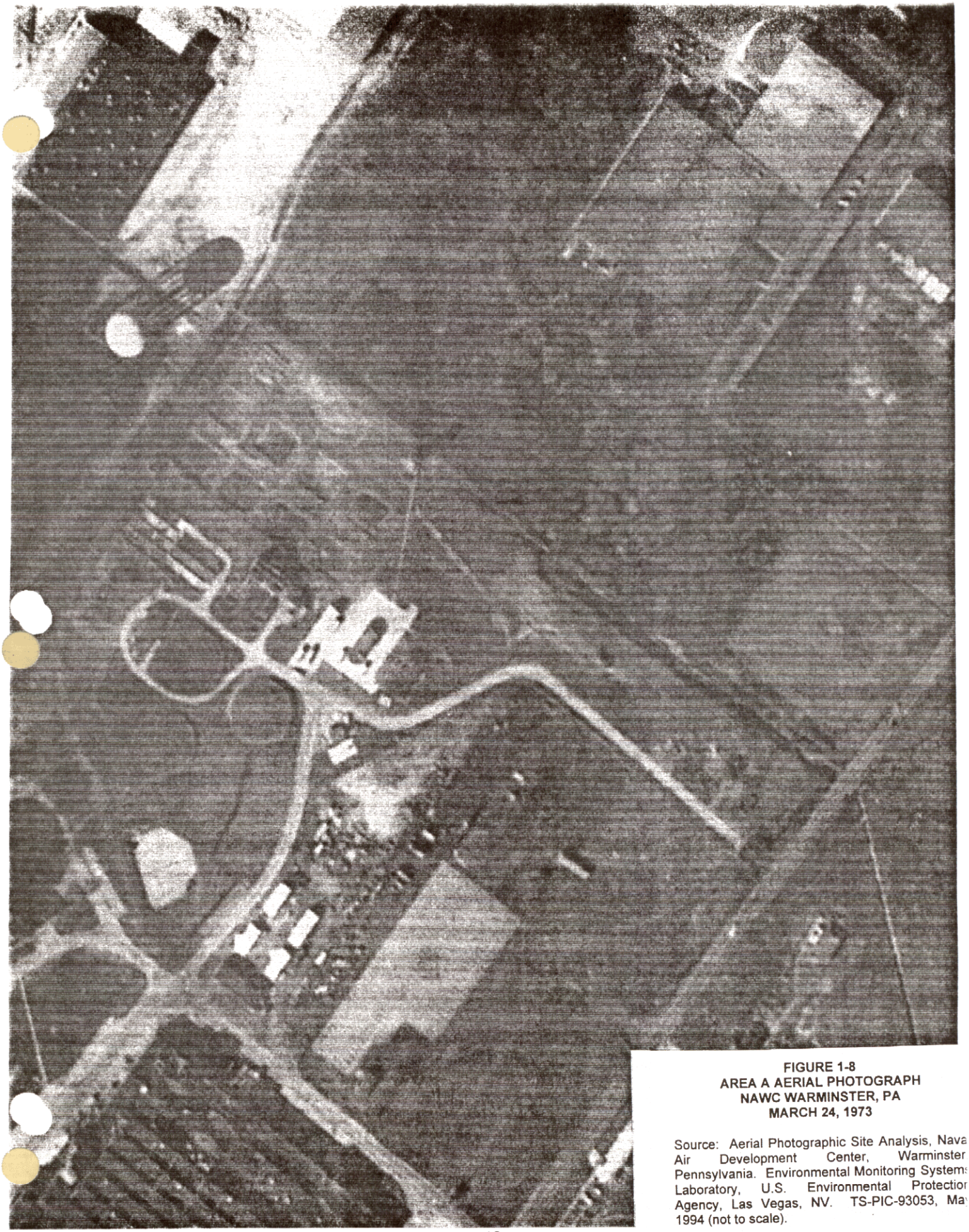


FIGURE 1-8
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
MARCH 24, 1973

Source: Aerial Photographic Site Analysis, Nava Air Development Center, Warminster Pennsylvania. Environmental Monitoring System Laboratory, U.S. Environmental Protectior Agency, Las Vegas, NV. TS-PIC-93053, Ma 1994 (not to scale).

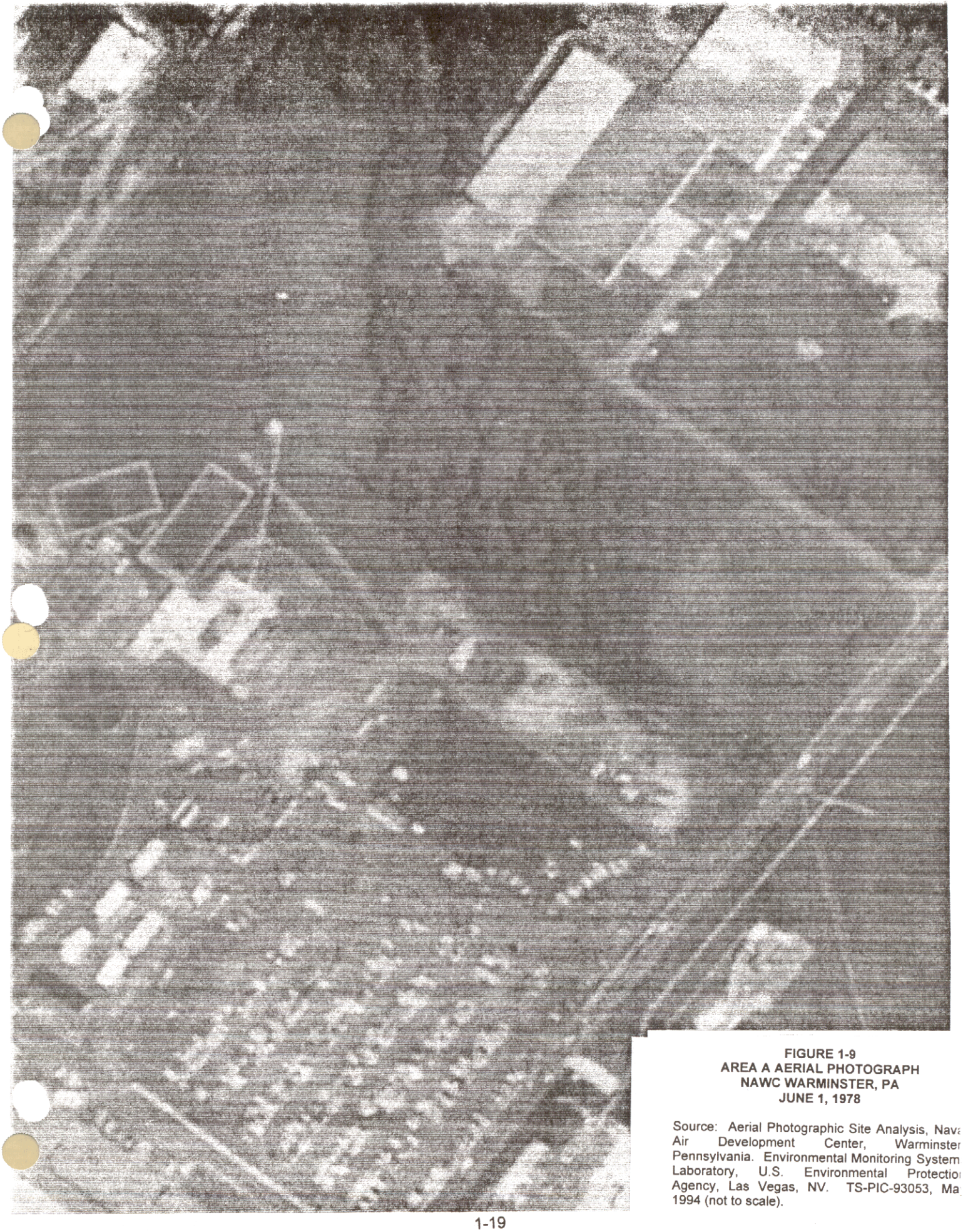


FIGURE 1-9
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
JUNE 1, 1978

Source: Aerial Photographic Site Analysis, Nava Air Development Center, Warminster Pennsylvania. Environmental Monitoring System Laboratory, U.S. Environmental Protectio Agency, Las Vegas, NV. TS-PIC-93053, Ma 1994 (not to scale).

FIGURE 1-10
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
JUNE 1988

Source: Aerial Photographic Site Analysis, Naval Air Development Center, Warminster, Pennsylvania. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, NV. TS-PIC-93053, May 1994 (not to scale).

FIGURE 1-11
AREA A AERIAL PHOTOGRAPH
NAWC WARMINSTER, PA
MARCH 8, 1990

Source: Aerial Photographic Site Analysis, Naval Air Development Center, Warminster, Pennsylvania. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, NV. TS-PIC-93053, May 1994 (not to scale).

ground scars (GS4) were present (Figure 1-6). In a photograph from March 1965, the ground scars were no longer evident; however, one of the wastewater treatment plant impoundments (i.e., Impoundment No.3) appeared to have been breached, releasing its contents northeastward toward the eastern half of Site 1. Photography from August 1971 showed a trench (TR8) at the same general location as P1. TR8 was roughly 230 feet long by 20 feet wide. By March 1973, the trench had apparently been filled (Figure 1-8). In its place, an area of mounded material (MM4) and disturbed ground (DG2) were identified at the northwestern edge of the estimated location of TR8. The area covered by DG2 was about 225 feet by 45 feet in size. In a photograph from June 1978, DG2 was no longer present (Figure 1-9). More recent photography since 1978 failed to identify any additional features in the immediate vicinity of Site 1 (Figures 1-10 and 1-11).

The review of historical photographs indicated that features in the vicinity of Site 1 were present while the impoundment area was receiving wastewater sludges, and historical photos indicate that disposal locations within Site 1 were active between 1940 and 1973. Collectively, these features comprise an area of about 17,000 square feet.

1.3.3 Summary of Previous Investigations at Site 1

As reported in the November 1996 Draft Phase III RI Report, during February 1980, soil borings were drilled to a depth of 11 feet within the vicinity of Site 1 in order to help investigate the likelihood of VOC soil contamination. Analysis of soil samples obtained from these borings at depths of 2 to 4 feet, 4 to 6 feet, and 9 to 11 feet detected trichloroethylene (TCE) concentrations ranging from 2.8 to 78 mg/kg. Higher concentrations were found within the first 6 feet of the borings.

Two monitoring wells were installed and sampled in October 1980. The wells were 60 and 300 feet deep. Groundwater samples from these wells contained TCE, 1,1,1-Trichloroethane (1,1,1-TCA), and chloroform. Higher contaminant concentrations were found in the shallow well.

In July 1982, one additional monitoring well and two observation wells were installed (JRB Associates, 1983). The observation wells were used to measure groundwater levels. The groundwater sample from the additional monitoring well contained antimony, nickel, zinc, and methylene chloride. The monitoring wells at Site 1 have been sampled several times since 1982.

In October 1988, SMC Martin observed that Site 1 was well covered and vegetated. Surface water drainage from the site was noted to flow toward the northeast.

An electromagnetic (EM) conductivity survey and soil gas survey were performed near Site 1 during Phase I. The EM survey consisted of seven northeast-to-southwest profile lines that were connected by a single

perpendicular line. A total of 39 soil gas readings were taken in the vicinity of this site. In addition, 12 confirmation soil borings were advanced to determine the presence of buried materials.

One surface soil sample was obtained from Site 1 during Phase II. This sample location corresponded to an area of high soil gas readings found during Phase I.

1.3.4 Previous Response Actions for Site 1

Based on preliminary RI results (including the results of supplemental investigations conducted in 1997 at Site 1), the Removal Site Evaluation Report for Area A Soils (including Site 1) was prepared in April 1998 (B&R Environmental, 1998a). This report focused on identifying areas where response actions were required and evaluated clean-up alternatives for impacted media. Based on this report, the Navy signed an Action Memorandum for a removal action at Site 1 in February 1999 (U.S. Navy, 1999). The purpose of this action was to address soils primarily contaminated with metals (antimony and cadmium) and TCE. The soil removal action was performed between August 1998 and January 1999.

The objectives of the removal action were to

- Protect industrial receptors from adverse health effects that could result from dermal contact and incidental ingestion of Site 1 subsurface soil.
- Protect groundwater quality by reducing infiltration of water into and through contaminated soils of concern.

The contaminated soils were excavated, transported to, and disposed in the GROWS Municipal Waste Landfill in Tulleystown, Pennsylvania and the CWM Chemical Services Hazardous Waste Landfill in Model City, New York. The soils did not require treatment prior to disposal. Soils were generally excavated to bedrock or a depth of about 12 feet below the ground surface (bgs). Two separate excavations (Excavation 1A and Excavation 1B) were made (Foster Wheeler, 1999). Verification samples were analyzed to confirm that no remaining subsurface soils exceeded the clean-up goals. The verification sample results are included in the analytical database for Site 1 soils as part of this report (Appendix A). The May 1999 Post Removal Summary Report, Area A, Sites 1, 2, and 3 prepared by TtNUS contains detailed information on the removal action (TtNUS, 1999a).

During removal activities at Excavation 1B, 10 drum carcasses and two laboratory bottles were encountered in the eastern half of the excavation (Foster Wheeler, 1999). Waste characterization data from the contents of some drums indicated that the contents were representative of hazardous waste under the Resource Conservation and Recovery Act (RCRA). The liquid remaining in the laboratory bottles was also analyzed; the results revealed that the primary component of the liquid was carbon tetrachloride.

Section 4.2.4.2 provides more detailed information regarding the removal action at the site, including the location of the soil removal and the results of the verification sampling.

1.4 SITE 2 DESCRIPTION AND HISTORY

Site 2 is located southeast of Site 1 and is also northwest of Jacksonville Road (Figure 1-3). Site 2 allegedly received wastewater treatment plant sludges from 1965 to 1970. The site reportedly consisted of two disposal trenches. A small stream that flows to the northwest is adjacent to the northeastern side of Site 2. To the southwest is a parking lot. The general area is bordered by Site 1 to the west, a former guardhouse and Site 3 to the east, a fuel storage area to the south, and the base fence line to the north.

The fuel storage area included a gas station with gasoline and diesel fuel underground storage tanks (USTs), four 15,000-gallon JP-5 USTs, and a storage building. Upon closure, Site 2 was covered with 2 feet of fill, regraded, and seeded.

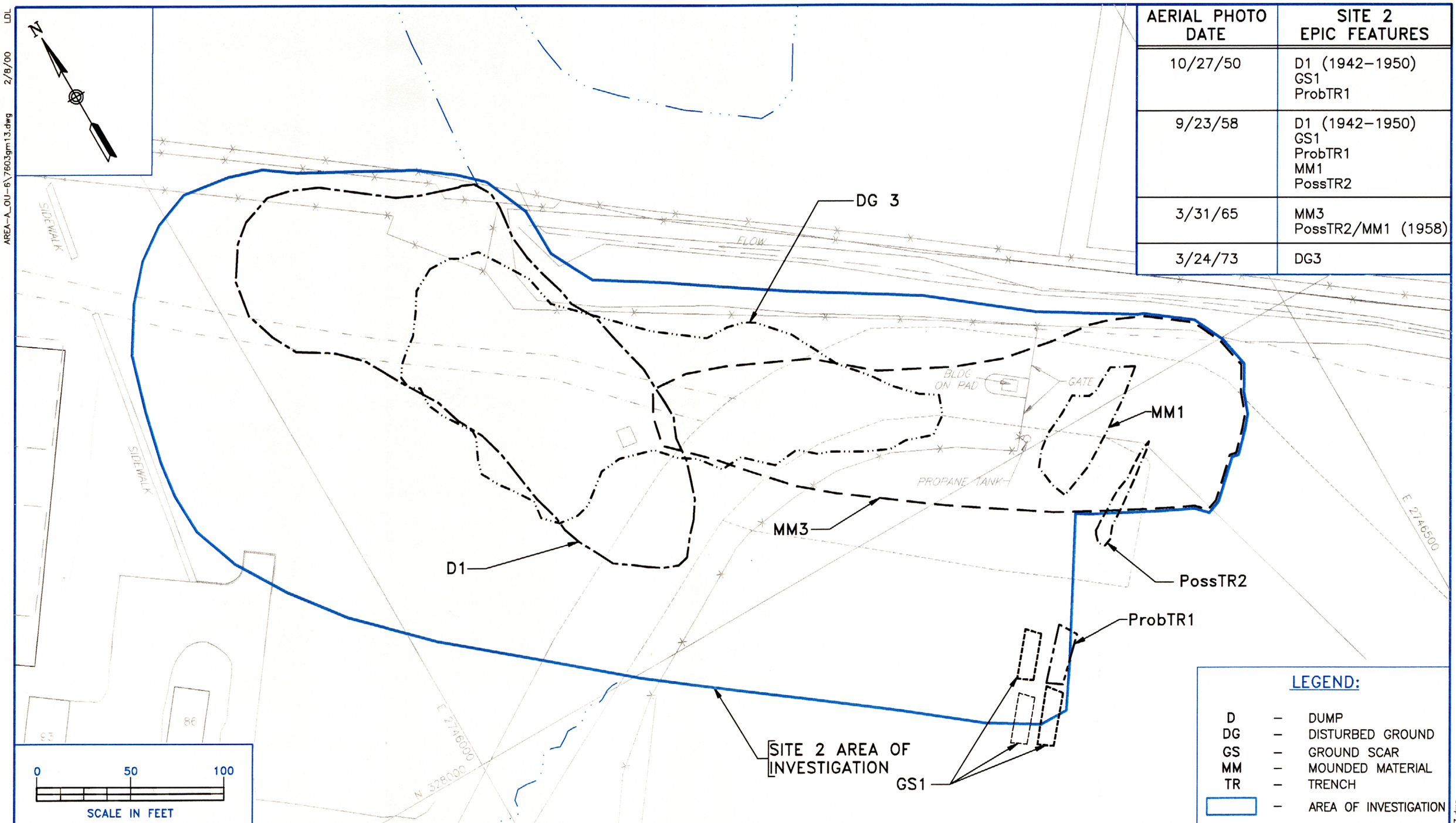
1.4.1 Site 2 History

Similar to Site 1, the Navy initially reported Site 2 as a disposal site in the Navy Shore Activity Disposal Fact Form (U.S. Navy, 1980) and Notification of Hazardous Waste Sites (U.S. Navy, 1981). The site allegedly consisted of two disposal trenches; each trench was approximately 12 feet wide by 200 feet long by 8 feet deep. The Navy also reported the disposal of 1,400 cubic yards of industrial wastewater sludge at this site (U.S. Navy, 1980).

The Aerial Photographic Site Analysis Report (EPIC, 1994) included the review of photographs from March 1938 thorough March 1990 and identified several waste disposal features in the vicinity of Site 2. These features are displayed in Figure 1-12. As reported in the EPIC report in a photo from April 1942, a relatively large dump (D1) was observed, along with scattered debris, ground scarring, and a nearby abandoned airplane (EPIC, 1994). On the eastern edge of D1 was a former streambed that drained portions of the base north of the main building complex. The dump was also visible in photographs through October 1950 (Figure 1-5). Three rectangular ground scars (GS1) and a probable trench (TR1) were identified south of the access road present in the October 1950 photograph (Figure 1-5).

Photography from September 1958 (Figure 1-6) showed that dumping was apparently no longer occurring in the vicinity of D1, GS1 and TR1. The areas of D1, GS1 and TR1 had been regraded and/or revegetated. However, the September 1958 photo did show a possible trench (TR2) and linear mounds of material

AERIAL PHOTO DATE	SITE 2 EPIC FEATURES
10/27/50	D1 (1942–1950) GS1 ProbTR1
9/23/58	D1 (1942–1950) GS1 ProbTR1 MM1 PossTR2
3/31/65	MM3 PossTR2/MM1 (1958)
3/24/73	DG3



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	OHM TRAILER AREA REMOVED.	LDL			

DRAWN BY LDL DATE 2/9/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

SITE 2
EPIC FEATURES
FORMER NAWC WARMINSTER
WARMINSTER, PA

CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY Jsa DATE 4/10/00
DRAWING NO. FIGURE 1-12
REV. 1

LDL 2/8/00 AREA-A_OU-6\7603gm13.dwg

AREA-A_OU-6\7603gm13.dwg

442 A03X

(MM1) in an area that was cleared and graded after 1950. TR2 and MM1 were located north of GS1 and TR1. In a photograph from March 1965 TR2 and DG1 were no longer present. Piles of mounded material (MM3) were identified, however, east of D1 and north of the access road present at that time (Figure 1-7). The piles of earthen material presumably consisted of soils and appeared to be in the same location as MM1, but was much more extensive than MM1. By October 1967, these piles were no longer evident (EPIC, 1994). In an August 1971 photograph reviewed in the EPIC report, parked trailers and the open storage of debris in the vicinity of Site 2 were identified, particularly between and on top of D1 and MM3 (EPIC, 1994). A relatively large area of disturbed ground (DG3) was noted in this same area in a March 1973 photograph (Figure 1-8). By 1977, DG3 was no longer present.

A review of historical photographs indicates that MM3, which is shown in aerial photos dated 1965 through 1967, may be the only disposal feature in the Site 2 area that existed between 1965 and 1970. With the exceptions of MM3 and DG3, which are noted in photos dated 1973 through 1977, all remaining features within Site 2 probably existed between 1942 and 1958. D1 appears in photos dated 1942 through 1950, which suggests that D1 may have been mistaken for a feature within Site 1. The photos do not indicate the presence of 200-foot trenches as reported by the Navy; however, it is possible that MM1 and MM3 represented materials that were subsequently buried by excavating trenches in the vicinity of Site 2. DG3, therefore, may indicate the general location of these trenches. The available historical photos indicate that disposal locations within Site 2 were most likely active between 1942 and 1977.

The Aerial Photographic Site Analysis report (EPIC, 1994) identified only one feature that fit the description of the two 200-foot by 12-foot trenches reportedly used for disposal of industrial wastewater sludge between 1965 and 1970 in Area A. This feature was TR8, as discussed as part of Site 1 in Section 1.3.2. It is possible that Site 1 and Site 2 are reversed in their respective descriptions and locations, as originally reported by the Navy. More specifically, Site 1 may have included D1 and Site 2 may have consisted of TR8. However, this distinction will not be addressed in the remainder of this report.

1.4.2 Summary of Previous Investigations at Site 2

In July 1982, four monitoring wells were installed and sampled (JRB Associates, 1983). These wells have been sampled periodically since 1982. Groundwater samples from wells near Site 2 contained low concentrations of 1,1-DCA, 1,1,1-TCA, methylene chloride, and various metals, including copper, chromium, nickel, and zinc.

During Phase I, SMC Martin noted contractors building a road over a portion of Site 2. Surface water drainage was observed to flow toward the northeast into a tributary of Little Neshaminy Creek.

Both EM conductivity and soil gas surveys were conducted near Site 2 as part of Phase II. The EM survey consisted of five northeast-to-southeast profile lines. The survey did not extend to the eastern half of Site 2.

A total of 42 soil gas readings were obtained in the vicinity of the western half of the site. In addition, 17 confirmation borings were drilled between the existing guardhouse and Site 1.

One subsurface soil sample was obtained from Site 2 during Phase II. This location corresponded to a soil gas anomaly where waste material was detected in confirmation borings drilled between the existing guardhouse and Site 1.

Both surface water and sediment samples were collected from the stream north of Sites 2 and 3 during Phases I and II. One Phase II sediment sample was taken from an orange-colored leachate along the stream bank adjacent to Site 2. A biological characterization of the area north of Area A was also performed during Phase I.

1.4.3 Previous Response Actions for Site 2

Similar to Site 1, the Removal Site Evaluation Report for Area A Soils was prepared in April 1998 (B&R Environmental, 1998a). Based on this report, the Navy signed an Action Memorandum for a removal action at Site 2 in February 1999 (U.S. Navy, 1999). The purpose of this action was to address surface and subsurface soils primarily contaminated with metals (e.g., antimony, cadmium, copper, lead, silver, and zinc), a variety of polycyclic aromatic hydrocarbons (PAHs), and several VOCs (bromomethane, methylene chloride, and trans-1,3-dichloropropene). The soil removal action was performed between October 1998 and January 1999. The objectives of the removal action were to

- Protect industrial receptors from adverse health effects that could result from dermal contact and incidental ingestion of Site 2 surface soil.
- Protect groundwater quality by reducing infiltration of water into and through contaminated soils of concern.
- Mitigate potential contaminant migration from Site 2 into the nearby stream.

The contaminated soils were excavated, transported to, and disposed in the GROWS Municipal Waste Landfill in Tulleystown, Pennsylvania. The nonhazardous soils did not require treatment prior to disposal. Surface soils were generally excavated to about 2 to 3 feet bgs. Deeper excavation extended from 4 to 7 feet below ground surface. Three separate excavations (Excavations 2A, 2B, and 2C) were made (Foster Wheeler, 1999). Verification samples were analyzed to confirm that no remaining surface soils exceeded the clean-up goals. The verification sample results are included in the analytical database for Site 2 surface soils as part of this report (Appendix A). Detailed information regarding the removal action, including the verification sampling program, is included in the May 1999 Post Removal Report, Area A, Sites 1, 2, and 3 (TtNUS, 1999a). Sections 4.3.3.2 and 4.3.4.2 provide more detailed information regarding the removal action at the site, including the location of the soil removal and the results of the verification sampling.

1.5 SITE 3 DESCRIPTION AND HISTORY

Site 3 is adjacent to the northwestern side of Jacksonville Road and is southeast of Site 2 (Figure 1-3). A parking lot is southwest of the site, and two NAWC Warminster housing areas are 600 feet and 1,000 feet away. The site reportedly was used from 1955 to 1965 as a burn pit for solvents, paints, roofing materials, and other unspecified chemicals. The pit was approximately 20 feet wide by 30 feet long by 10 feet deep and may have been constructed as a subsurface "cage." Residue from the pit was occasionally removed and deposited at an unknown area at NAWC Warminster.

Surface water drainage from the site is toward the northeast into the unnamed tributary near Sites 1 and 2. Groundwater flow may be to the north. Upon closure, Site 3 was reportedly backfilled with on-base soil and regraded.

1.5.1 Site 3 History

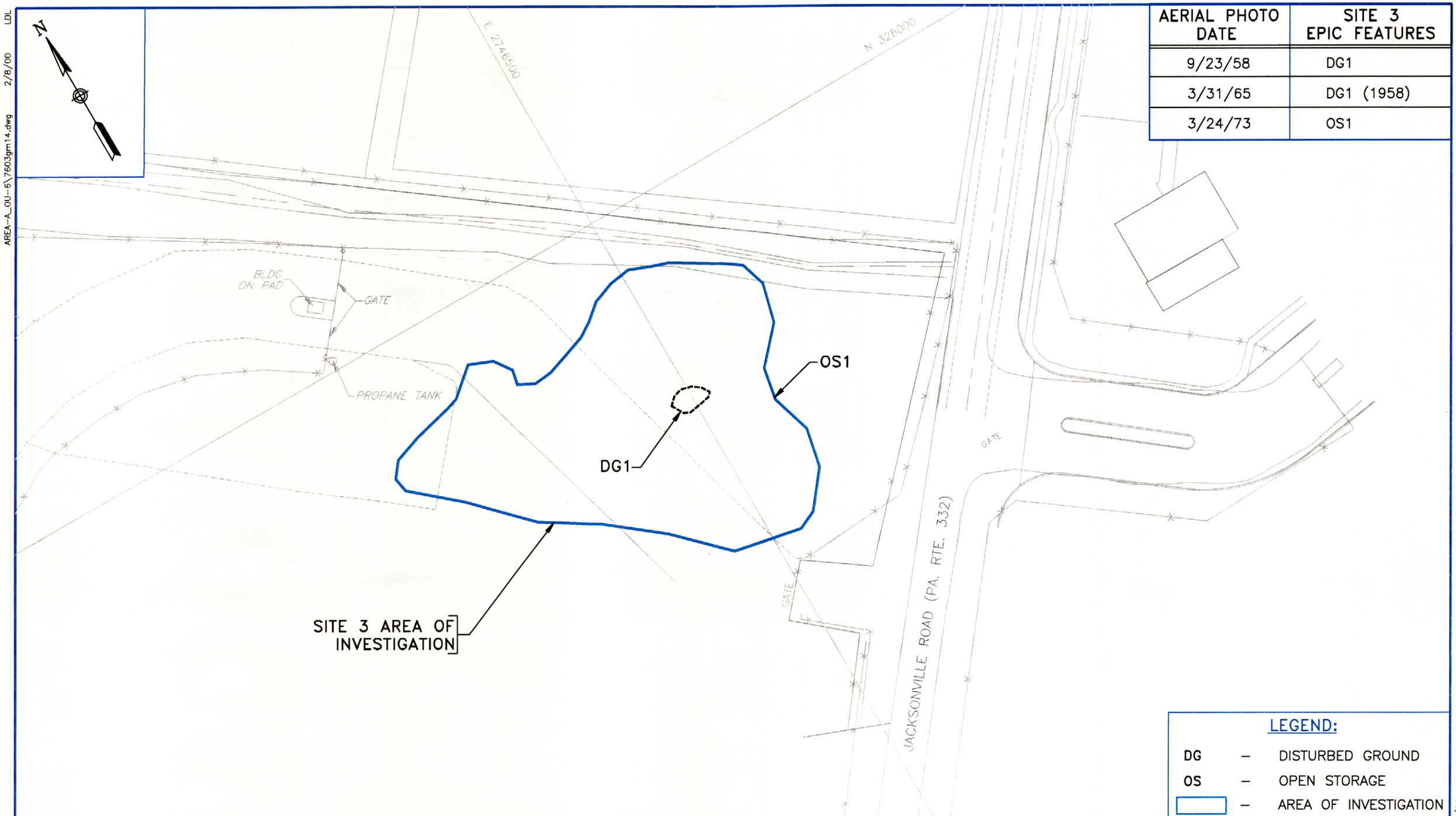
Like Sites 1 and 2, the Navy initially reported Site 3 as a disposal site in the Navy Shore Activity Disposal Fact Form (U.S. Navy, 1980) and Notification of Hazardous Waste Sites (U.S. Navy, 1981). The Aerial Photographic Site Analysis Report (EPIC, 1994) included the review of photographs from March 1938 thorough March 1990 and identified several waste disposal features in the vicinity of Site 3. These features are displayed in Figure 1-13.

Photography from September 1958 showed an area of disturbed ground (DG1), perhaps due to vehicle traffic east of TR2 and MM1 (Figure 1-6). In a March 1965 photograph the disturbed ground is no longer present (Figure 1-7). It is noted that one probable tank and other equipment are now present at this location.

By August 1971, an open storage area (OS1) was observed in the vicinity of DG1, with disturbed ground and erosion noted in the EPIC report (EPIC, 1994). The area of OS1 expanded in the late 1970s and mounded material and equipment were identified in storage at this location in 1973 photography (Figure 1-8). No significant change was noted in 1978 in the EPIC review and operations at OS1 were apparently discontinued by March 1985 (EPIC, 1994).

No evidence of a pit or open burning was identified from the aerial photo analysis; however, disturbed ground and open storage were noticed in the area (EPIC feature DG1, OS1) within the 1958 to 1973 time span. The review of historical photographs indicates that DG1, which is shown in aerial photos dated 1958 through 1965, may be the best match for the burn pit reported at this location.

AERIAL PHOTO DATE	SITE 3 EPIC FEATURES
9/23/58	DG1
3/31/65	DG1 (1958)
3/24/73	OS1



LEGEND:

DG – DISTURBED GROUND

OS – OPEN STORAGE

AREA OF INVESTIGATION

0 50 100

SCALE IN FEET

DRAWN BY LDL	DATE 2/29/00	Tetra Tech NUS, Inc.	SITE 3 EPIC FEATURES FORMER NAWC WARMINSTER WARMINSTER, PA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. N62472-90-D-1298

OWNER NO. 7603

APPROVED BY Jsa DATE 4/10/00

DRAWING NO. FIGURE 1-13 REV.

LDL 2/8/00 AREA-A_OU-6\7603gm14.dwg

AREA-A_OU-6\7603gm14.dwg

442A044

1.5.2 Summary of Previous Investigations at Site 3

In July 1982, one monitoring well was installed adjacent to Site 3 (JRB Associates, 1983). This well has been sampled periodically since 1982. Groundwater samples from this well contained 1,1,1-TCA, methylene chloride, antimony, copper, and nickel.

During October 1980, SMC Martin noted construction debris along the banks of the unnamed tributary. A roadway built over portions of Site 2 may have been placed over a large portion of Site 3 as well.

EM and soil gas surveys were performed near Site 3 during Phase I. The EM survey consisted of a 60- by 60-foot grid using a 15-foot station spacing. A total of 26 soil gas readings were made near Site 3 in the area bordered by the base fence, the access road, and Jacksonville Road. Also, seven confirmation borings were drilled in the same general area.

Two soil samples were taken from Site 3 during Phase II. These sample locations corresponded to an area of elevated soil gas readings and/or waste materials detected during the Phase I work.

Surface water and sediment samples were also obtained from the stream north of Site 3 during Phases I and II.

1.5.3 Previous Response Actions for Site 3

Similar to Sites 1 and 2, the Removal Site Evaluation Report for Area A Soils was prepared in April 1998 (B&R Environmental, 1998a). Based on this report, the Navy signed an Action Memorandum for a removal action at Site 3 in February 1999 (U.S. Navy, 1999). The purpose of this action was to address surface soils contaminated with PAHs, including anthracene, benzo(a)anthracene, benzo(a)pyrene, and fluoranthene. The soil removal action was performed between October 1998 and November 1998. The objectives of the removal action were to

- Protect groundwater from adverse effects due to leaching of contaminants from soils.
- Mitigate potential contaminant migration from Site 3 into the nearby stream.

The contaminated soils were excavated, transported to, and disposed in the GROWS Municipal Waste Landfill in Tulleystown, Pennsylvania. The nonhazardous soils did not require treatment prior to disposal. Soils were generally excavated to a depth of about 2 feet below the ground surface. One excavation

(Excavation 3) was made (Foster Wheeler, 1999). Verification samples were analyzed to confirm that no remaining surface soils exceeded the clean-up goals. The verification sample results are included in the analytical database for Site 3 surface soils as part of this report (Appendix A). Additional information regarding the removal action is detailed in the May 1999 Post Removal Summary Report, Area A, Sites 1, 2, and 3 (TtNUS, 1999a).

1.6 IMPOUNDMENT AREA DESCRIPTION AND HISTORY

Brewster Aeronautical Corporation and NAWC Warminster formerly operated up to eight unlined impoundments or lagoons for storage of wastewater treatment plant sludges. The sludges stored in these impoundments were generated by the industrial wastewater treatment plant, which is located in the northern corner of Area A (Figure 1-3), in what is now primarily an open grassy area. Each lagoon had approximate dimensions of 60 feet wide by 75 feet long, with depths of approximately 8 to 10 feet, based on historical facility drawings. The lagoons were reported as closed in 1973 by PADEP, backfilled, and replaced with two concrete-lined surface impoundments. The sludges from the lagoons were reportedly disposed at Sites 2 and 6 according to the Navy (U.S. Navy, 1980), although disposal at other locations at the base cannot be ruled out. The impoundment area includes the location of the current groundwater treatment plant.

1.6.1 Impoundment Area History

The first impoundments were installed as early as 1940, according to historical aerial photography. By October 1950, all eight impoundments were operational. A possible breach of Impoundment No. 3 was noted in a photograph from March 1965. The breach may have spilled the liquid contents of the impoundment northeastward toward Site 1 (Figure 1-7). The impoundments were replaced in 1973 by two larger rectangular concrete-lined basins, as evidenced by an August 1977 photograph.

An industrial treatment facility (Building Nos. 20 and S-259) was included as part of the wastewater treatment plant. This facility received wastewater from Navy research and development (R&D) laboratories (e.g., electroplating, painting, photography laboratories), aircraft hangar operations, and aircraft washing operations (EA, 1995). Industrial wastewater was pre-treated through neutralization and metals precipitation. The wastewater was treated with ferrous sulfate, lime, and chlorine in a process that formed sludge. Organic constituents were not treated by the treatment facility. The sludge stored in the impoundments was designated as wastewater treatment sludge from electroplating operations and assigned an EPA hazardous waste number of F006.

The first concrete-lined surface impoundment (Lagoon No. 1), constructed in 1973, was closed in accordance with an approved closure plan in 1987 (U.S. Navy, 1987). It was then lined with a synthetic

membrane and used to accept residual nonhazardous waste sludge (EA, 1995). The second concrete-lined surface impoundment (Lagoon No. 2) was temporarily retained to accept nonhazardous sludge and was emptied and cleaned in December 1991 (BCW, 1992). A closure report for the second impoundment was submitted to the PADEP in April 1994 (U.S. Navy, 1994). PADEP certified that this impoundment was closed in August 1994.

1.6.2 Summary of Previous Investigations at Impoundment Area

During the closure of Lagoon No. 1, the Navy performed sampling and analysis of concrete samples from the liner of the lagoon. Six samples were collected and analyzed for extraction procedure toxicity (EP TOX) metals plus cyanide. Barium was detected in all six samples. Arsenic and mercury were detected in five and two samples, respectively. No analytes were detected above RCRA regulatory levels (SRE Analytics, 1987).

As part of the closure of Lagoon No. 2, the Navy performed sampling and analysis of concrete samples from the lagoon's liner. One sample per sidewall and two bottom samples were collected, for a total of six samples. The samples were analyzed for EP TOX metals plus nickel and cyanide (total and free). Barium was detected in all six samples and chromium was found in one sample. All concentrations were below RCRA regulatory levels for hazardous waste determination (BCW, 1992).

Following the emptying and steam cleaning of Lagoon No. 2, additional soil borings were drilled in 1992 outside the lagoon perimeter, at depths of 5 and 10 feet bgs. This was necessary because the side and backwalls of lagoon No. 2 had separated. The soil boring samples were analyzed for toxicity characteristic leaching procedure (TCLP) metals plus cyanide (total and free). Trace levels of arsenic, barium, chromium, and lead were reported in one or more samples from the 5-foot depth, and a trace level of cadmium was detected in one sample from the 10-foot depth. No analytes were reported above the RCRA regulatory levels (Probe Environmental, 1992).

In April 1994, the Navy conducted sampling and analysis of subsurface soils underlying the approximate location of the future groundwater treatment plant (HNUS, 1994). The objective of this work was to verify that material beneath the plant was not a source of contamination. Six borings were drilled and eight samples were obtained for analysis. The results indicated that there was residual contamination in the vicinity of the plant. However, the majority of the analytical results were less than the applicable PADEP interim clean-up standards for contaminated soils and the EPA risk-based soil screening criteria.

In May 1995, the Navy began constructing a groundwater treatment plant on top of the former locations of Impoundment Nos. 1 and 8. During the excavation of the foundation and footings for the plant, a small quantity of contaminated soils was detected. The soils were analyzed and samples contained slightly elevated levels of several metals, presumably from a former impoundment located in this area. The specific metals included barium, cadmium, and chromium. As part of this effort, nine soil borings were drilled and subsurface soil samples were collected and tested for TAL metals near and beneath the proposed foundation of the treatment building (U.S. Navy, 1995). Samples were obtained at depths between 6 and 10 feet bgs. In all the boring samples, analytes were detected at concentrations comparable to background levels. With the exception of beryllium, in one sample, there were no exceedances of both background levels and residential screening criteria.

1.6.3 Previous Response Actions for Impoundment Area

Based on the May 1995 sampling results, the Navy conducted an excavation program to remove unacceptable metal levels of subsurface soil contamination. To address the contamination, the Navy excavated approximately 550 cubic yards of soil beneath the foundation and within the perimeter of the treatment building. Additional soil was also excavated within Area A during the installation of the underground piping to the building. Clean stone fill was used to restore the excavated areas.

1.7 DESCRIPTION AND HISTORY OF AREA A TANKS

Several above-ground and underground storage tanks were formerly present south of Site 2 and west of the existing access road within Area A. While the scope of the RI work was not intended to address these tanks, a brief summary of those tanks in the vicinity of Area A is provided for informational purposes. Additional details are provided in the Navy Storage Tank Report for NAWC Warminster (EA, 2000).

As discussed in Section 1.4, a fuel storage area existed south of Site 2 and southeast of the former impoundment area. Tanks in the fuel storage area were excavated and removed by the Navy in 1997. During excavation work, some soils appeared to be stained by petroleum-derived products. These soils were excavated and sent off base for disposal. The entire area was then regraded and seeded.

An additional UST, Tank No. 18, was located south of the fuel storage area. This tank was installed in 1953 as a 2,000-gallon UST. The Navy identified Tank No. 18 as a RCRA hazardous waste management unit in 1983, and it was briefly permitted under RCRA for storage of waste oils and used solvents generated during automobile and aircraft maintenance. In February 1990, a small leak was discovered between the tank's funnel opening and the fill area. The tank was removed and closed in

January 1993. In April 1993, the Navy collected six soil samples in the vicinity of the former tank location. The samples were analyzed for VOCs, benzene, toluene, ethylbenzene, and xylene (BTEX), total petroleum hydrocarbons (TPH), and PCBs (ITS, 1993). TPH results ranged from non-detect (56U mg/kg) to 3,100 mg/kg.

In October 1999, six soil boring samples were collected from three separate borings downgradient of the former location of Tank No. 18 (Tetra Tech NUS, 1999e). PID readings were recorded and petroleum odors were encountered in all three borings at depths below 4 feet. Low concentrations of several VOCs and semivolatile organic compounds were detected in these samples; however, none of the concentrations exceeded soil-screening criteria for an industrial land use scenario. Among the other sample results, one pesticide, beta-BHC, slightly surpassed the respective screening criteria. Arsenic levels also exceeded the screening criteria in three soil samples; concentrations ranged from 3.9 to 5.9 mg/kg (the soil screening value was 3.8 mg/kg).

1.8 CURRENT STATUS OF AREA A

As part of the DOD closure of NAWC Warminster, the FLRA has been given the opportunity to develop the property and bring new opportunities for employment at the base. The redevelopment plan for the base calls for industrial land use in the vicinity of Sites 1, 2, and 3 and the Impoundment Area (Ernst and Young, 1998; FLRA, 1999). Adjacent to Site 1 and the Impoundment Area, the Warminster Municipal Authority (WMA) plans to develop a wastewater treatment plant for its use. The Navy plans to transfer land in the vicinity of Site 1 to WMA as part of a public benefit conveyance (PBC) through the U.S. Department of Health and Human Services (HHS).

Near Site 2, a morgue for the Bucks County Department of Health is planned. The Navy intends to transfer land associated with the morgue to Bucks County as part of a second PBC, also through HHS. The remaining property in the vicinity of Area A, including Site 3, will be transferred to the FLRA. All property transfers should be completed in 2000.

The Navy is currently preparing final RI and FS reports for Area A groundwater (OU-1). Once completed, the final remedy for Area A groundwater will be selected by the Navy and EPA. This remedy will be explained in the final ROD for Area A groundwater. Information from the ongoing Area A groundwater performance monitoring program will be used to evaluate the effectiveness of the interim groundwater remedy and to assist in developing the final groundwater clean-up plan for Area A groundwater.

In September 1999, the Navy began a long-term stream monitoring program concerning the unnamed tributary to Little Neshaminy Creek north of Area A. As of March 2000, three rounds of stream monitoring had been conducted (TtNUS, 1999f and 2000b). The initial long-term monitoring program will be completed

by September 2002, at which time the Navy will evaluate the need for further investigation or additional monitoring.

1.9 REPORT ORGANIZATION

This report presents the results and recommendations related to the following field activities performed at Area A:

- Electromagnetic surveys
- Soil gas surveys
- Test pit excavations
- Surface water and sediment sampling and analysis
- Surface soil sampling and analysis
- Subsurface soil sampling and analysis
- Wetlands assessment
- Surveying
- Performance of response actions

Section 1.0 discusses the purpose, scope, and objectives of the report and provides a background summary for Area A media other than groundwater. Section 2.0 details the field activities and other tasks performed (with an emphasis on Phase III RI work) and describes the objectives and methods of each investigative task conducted at the site. Section 3.0 presents the physical characteristics of the site based on existing literature, previous investigations, and recently developed information. Section 4.0 describes the nature and extent of contamination discovered at Area A during field investigation tasks. Section 5.0 summarizes the routes of migration and persistence of contaminants found at the site. These two factors are used to determine the possibility of contamination reaching areas of public or environmental concern. Section 6.0 presents the potential risks posed by the site to human health and the environment given the limiting factors of contaminant fate and transport.

Several appendices have been enclosed as part of the RI report; these present specific results of the field investigations (e.g., analytical data) and other reference information.

2.0 AREA A INVESTIGATIONS

2.1 INTRODUCTION

This section summarizes the nature of RI work performed at Area A. Specific findings regarding the physical characteristics of the area and the nature and extent of contamination are presented in Sections 3.0 and 4.0.

RI work addressing soils, surface water, and sediment in the vicinity of Area A was conducted in phases, as discussed in Section 1.2.3. The Phase I RI (SMC Martin, 1991) included limited soil gas and geophysical surveys, soil borings, test pits, and surface water and sediment sample analysis. The Phase II RI (HNUS, 1992) was limited to sampling of soils, surface water, and sediment from several locations within and near Area A. Based on the findings of the Aerial Photographic Site Analysis Report (EPIC, 1994), a more comprehensive Phase III RI was performed beginning in 1995.

The Phase III RI work plan to study NAWC Warminster was submitted as a final document to the Naval Facilities Engineering Command (NAVFACENGCOM), Northern Division, on January 16, 1995 (HNUS, 1995a). The work plan incorporated comments received from Restoration Advisory Board (RAB) members. The plan described RI activities that were to be implemented to help characterize the potential sources of contamination within Areas A, B, and C.

Phase III RI field activities focused on characterizing surface soils, subsurface soils, buried materials, surface waters, and sediments potentially impacted by suspected sources at Area A. The results from the Phase III RI for Area A were reported in a draft Phase III RI report, which was issued in November 1996 (B&R Environmental, 1996a).

Following the review of the draft Phase III RI report, the Navy conducted several supplemental soil investigations at Area A to

- Address remaining concerns or data gaps regarding the nature and extent of contamination related to Area A sites.
- Support removal actions.
- Verify that the removal action clean-up goals were met. The supplemental field work was performed between June 1998 and October 1999.

This section primarily discusses the field investigation procedures that were performed at Area A during the Phase III RI. Field work activities conducted as part of the Phase I RI (SMC Martin, 1991) and as part of the Phase II RI (HNUS, 1992) are discussed in the Phase I and II RI reports and are not presented in this section. However, the collective results of all RI work at Area A are summarized in Section 4.0. Table 2-1 summarizes the RI field work and supporting activities performed at Area A during all three RI phases.

2.2 GENERAL FIELD INVESTIGATION PROCEDURES

The Phase III RI field work at Area A was performed between January 1995 and October 1999. Tasks included the following:

- EM survey
- Soil gas surveys
- Surface water and sediment sampling and analysis
- Surface soil sampling and analysis
- Subsurface soil sampling and analysis, including test pits and soil borings
- Wetlands assessment
- Surveying

2.2.1 Scope of Work

The Phase III RI work for Area A focused on characterizing the potential sources of contamination, particularly with regard to soils and wastes. In addition, a surface water and sediment sampling program was conducted to evaluate the impacts of Area A on the unnamed tributary to Little Neshaminy Creek.

The primary tools of investigation included a soil gas survey, test pits and soil borings (with subsurface soil/wastes sampling), and surface soil/waste sampling. These methods were applied, as appropriate, in an integrated manner to characterize the potential source areas of contamination targeted for investigation.

A soil gas survey was employed in areas of suspected disposal of wastes containing volatile organics. One objective of the soil gas survey was to identify potential sources of the chlorinated VOCs detected in local groundwater. The locations of the soil gas survey took into consideration identified potential sources from aerial photos, the Phase I RI geophysical survey, past investigation data, field observations, and historic information regarding the locations of subsurface disposal sites.

TABLE 2-1
SUMMARY OF RI FIELD WORK AND OTHER ACTIVITIES AT SITES 1,2,3 AND THE FORMER IMPOUNDMENT AREA
NAWC WARMINSTER, PENNSYLVANIA

TASK	PHASE I RI	PHASE II RI	PHASE III RI	COMMENTS
Electromagnetic (EM) Survey	1,3,4	2	1,2,3	
Soil Gas Survey	1,3,4		1,2,3,4	
Surface Soil Sampling and Analysis		1	1,2,3	
Subsurface Soil Sampling and Analysis using Soil Borings		1,2,3	1,2,3,4	
Subsurface Soil Sampling and Analysis using Test Pits			1,2,3	
Confirmation Soil Borings and Test Pit Excavations	1,3,4		1	
Surface Water and Sediment Sampling and Analysis	2,3	2,3	1,2,3,4	
Biological Characterization			Area A	
Wetlands Assessment			1,2,3,4	
Aerial Photograph Interpretation			1,2,3,4	
Verification Sampling and Analysis			1,2,3	Post-Removal

1 - SITE 1 TASK
2 - SITE 2 TASK
3 - SITE 3 TASK
4 – IMPOUNDMENT AREA TASK

Test pits and borings were used to characterize actual subsurface conditions in potential subsurface disposal sites. The decision regarding which of these investigative methods was proposed was based on expected site characteristics and cultural features. The locations of the test pits/borings were selected based on the results of the Phase III RI soil gas and Phase I RI geophysical surveys, as well as on aerial photo records, field observations, and previous field work findings. Subsurface soil/waste samples were obtained from the test pits/borings to characterize the encountered materials.

Surface soil/waste sampling was conducted in areas where surface disposal of wastes was a potential concern. In areas of obvious waste disposal on the ground surface (i.e., waste piles or stained soils), the samples were taken directly from the affected materials. In areas of suspected surface disposal where no visible sign of wastes was evident, samples were obtained at various points within the suspected area of disposal. In addition, a basewide background surface soil sampling program was performed to provide a background database with which to compare potentially impacted soil results.

Several supplemental investigations were conducted after the draft Phase III RI report was submitted to further characterize the surface and subsurface soil contamination at Area A:

- From May to July 1998, additional surface and subsurface soil samples were collected at Sites 1, 2, and 3. The results were presented in separate letter reports (B&R Environmental, 1998b, 1998c, and 1998c).

- In August 1998, a removal action was begun at Site 1 (Excavation 1A) based on the RI work and the supplemental soil investigation. The analytical results of verification samples were presented in letter reports dated September 10 (TtNUS, 1998b), October 7 (TtNUS, 1998c), and October 27, 1998 (TtNUS, 1998d).

- In September 1998, removal actions were begun at Site 1 (Excavation 1 B) and Site 2 (Excavations 2A and 2B). The results of the Excavation 1B verification sampling and analysis were reported in letter reports dated September 10 (TtNUS, 1998b), November 12 (TtNUS, 1998e), and November 25, 1998 (TtNUS, 1998f); the results of the Excavation 2A verification sampling and analysis were reported in letter reports dated October 29 (TtNUS, 1998g), November 12 (TtNUS, 1998h), and November 25, 1998 (TtNUS,1998i); and the results of the Excavation 2B verification sampling and analysis were reported in a letter report dated December 28, 1998 (TtNUS, 1998j).

- In October 1998, a supplemental subsurface soil investigation was performed at Site 3. The analytical results were presented in a letter report dated October 30, 1998 (TtNUS, 1998k).

- In October 1998, removal actions were begun at Site 2 (Excavation 2C) and Site 3. The results of the verification sampling and analysis were presented in letter reports dated October 27, 1998 for Excavation 2C (TtNUS, 1998l) and November 13, 1998 for Site 3 (TtNUS, 1998m).

- In December 1998, a geophysical survey was conducted at Sites 1 and 2. The results of this investigation were reported on December 31, 1998 (TtNUS, 1998n).

- In October 1999, a supplemental subsurface soil investigation was completed at Site 2, Site 3, and the former location of Tank No. 18. The sampling and analysis results were reported on November 8, 1999 (TtNUS, 1999e).

Sampling plans were prepared for each of the supplemental investigations. The results of all verification sampling and analyses programs were presented in the May 1999, Post Removal Summary Report Area A, Sites 1, 2, and 3 (TtNUS, 1999a). The methodologies for the Phase III RI field work are explained in the remainder of this section.

2.2.2 Electromagnetic Surveys

During Phase III, EM conductivity surveys were used to delineate areas of underground anomalous conductivity. Areas of anomalous conductivity can indicate areas of waste burial, contaminated groundwater, and filling or other subsurface disturbance. The surveys also were important in indicating where metallic objects may be buried. This information was used in combination with the results of the soil gas surveys to indicate possible site boundaries, orientations of trenches or pits, depths of burial, and areas of waste and/or contamination.

EM surveys were conducted in two modes. The conductivity (quadrature) mode was used to map electrical conductivity anomalies possibly caused by the presence of contaminants or wastes. The compensation (in-phase) mode was used to map areas possibly containing large metallic objects.

The field work was performed using an EM31-D terrain conductivity meter. The EM31-D works by transmitting an electromagnetic signal from the transmitting coil. This signal induces a secondary signal in the ground that is then measured by a receiving coil. The phase change in the signal received from the transmitted signal is proportional to the ground conductivity. The amplitude of the portion of the signal received, which is in phase with the transmitted signal, can be used to identify highly conductive materials, such as metal.

Before the survey at Area A was conducted, the EM31-D was used to test these areas for cultural interferences before a full-scale survey was completed across the sites. Asphalt-paved areas near Site 2 were not suitable for the acquisition of competent data; however, Site 1, the remainder of Site 2, and Site 3

could be covered with reasonable success except in close proximity of fences, light posts, the wastewater lagoons, and other cultural objects.

Readings are relative, not absolute; therefore, all surveys utilized profile lines to establish grid systems to aid in establishing relative differences across the target areas. Profiles utilized maximum station spacings of 30 feet, and the grids consisted of intersecting profile lines. Survey lines were generally laid out perpendicular and/or parallel to the orientation of the linear features within each survey area as identified in the Phase III RI work plan (HNUS, 1995a). The number of profile lines recorded and the areas covered were significantly increased, at the direction of the Navy, from those indicated by the work plan. The actual number and location of the EM survey profile lines are shown and discussed in the site-specific sections.

The length, spacing, and orientation of the profile lines were determined using a compass and measuring tapes. Profile line spacings vary from 20 to 50 feet based on the size of the investigation area or target and on the locations of any obstructions. Conductivity measurements were recorded on 5-foot station spacing intervals for all profile lines. Reference points were placed or marked along each profile line so they could be accurately located during subsequent RI activities. The locations of the EM survey lines were also referenced to nearby permanent structures whenever possible.

The EM-31 was set up and functional tests and field calibrations were performed according to the manufacturer's instructions at the beginning of each day and before surveys were performed at each site. Functional tests included a battery test and zero adjustment, if necessary. Field calibration included a check of the instrument phasing (and adjustment, if necessary) and a check of the instrument's sensitivity. These tests and calibrations were performed in a background setting free of buried waste or other cultural sources of interference, based on available information. The automatic data logger used with the EM-31 was programmed, operated, and downloaded according to the manufacturer's instructions.

The EM-31 was operated in the normal (face-up) orientation and at the normal (hip-level) height of approximately 1 meter above the ground surface. At each survey point, both the quadrature and inphase measurements were recorded into the attached automatic data logger by pressing the EM-31 record button. Both measurements were also visually observed on the instrument display gauge using the most sensitive range setting possible for each set of values. During the survey, all potential sources of interference such as fences and overhead or underground utility lines were noted, along with their orientation and location with respect to the survey points. Any ground surface features that might correspond with EM anomalies were also noted. Whenever possible, survey profiles were extended at least three stations beyond any anomalous readings.

Ground conductivity data underwent a preliminary quality and content review in the field as they were being acquired. All geophysical data were downloaded and reviewed at the end of each day of acquisition. Electronic data files were created and saved, and the data were displayed in tabular numerical form as

graphs of individual profile lines and as contour maps of data from all profile lines. Site sketch maps showing the locations of all profile lines, significant cultural features, EPIC features marked by the Navy, and any evidence of soil disturbance/waste disposal were drawn at a scale of 1 inch = 40 feet. The site sketch maps and graphs of quadrature and inphase measurements (terrain conductivity and percent of phase transmitted) versus station number for selected profile lines are included in Appendix B. Additional data were acquired as necessary following review of the existing data.

The EM-31 data were processed and interpreted using the equipment manufacturer's (Geonics) DAT31 software. The raw digital data were viewed in profile format, survey lines were gathered into data groups, and the data were exported as ASCII files. The exported ASCII data files included the station and line location, terrain, (apparent) conductivity, and in-phase (metal detection) data. The data were then imported into OASIS software where digital filters were used as necessary to optimize interpretations.

The data were converted and imported into GEOSOFT, where they were translated into the site coordinate system. Data were gridded and then color contoured by creating a color zone file based upon an equal area zoning method. The equal zoning method was selected because it displays the full dynamic range of the data that may not otherwise be apparent using linear or log-linear zoning methods.

The data were color contoured such that shades of blue represent anomalously low data values and shades of orange, red, and purple represent anomalously high data values. Shades of green were color contoured to represent background conditions.

A planimetric map of the site was overlain onto the color-contoured data. Site surface features and the site geophysicist notes were then used to make final interpretation regarding the possible origins of the observed anomalous responses. Observed anomalous responses were annotated on each map.

The survey grid in the northwestern part of Area A (near Site 1) consisted of 22 parallel, southwest-northeast-trending profile lines evenly spaced 20 feet apart (Figure 2-1). The survey grid in the southern part of Area A (near Sites 2 and 3) consisted of 21 parallel, northwest-southeast-trendingprofile lines evenly spaced 20 feet apart. The survey grid in the small northeastern section of Area A across the stream from Parking Lot No. 2 (Zone B) consisted of 14 parallel, northwest-southeast-trending profile lines evenly spaced 20 feet apart, with three additional profile lines infilled at 10-foot spacing.

Additional geophysical surveys were conducted in the vicinity of Sites 1 and 2 during December 1998. The purpose of the surveys was to locate any remaining buried drums and other ferrous metal objects and to clear drilling locations for the Area A extraction well network. The geophysical surveys consisted of both a magnetic survey utilizing two Geometrics G-858 cesium vapor magnetometers and an electromagneric survey using one Geonics EM-61 metal detector.

LDL 3/1/00 AREA-A_OU-6/7603cm01.dwg

N

LEGEND

SURVEY LINE

0 150 300

SCALE IN FEET

DRAWN BY LDL	DATE 3/1/00	Tetra Tech NUS, Inc.	AREA A GEOPHYSICAL SURVEY GRID PHASE III RI FORMER NAWC WARMINSTER WARMINSTER, PA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-1	REV.

7603cm01.dwg

442 A05Y

A local grid system was established using a compass and tape measure. The long axis of the local grid was oriented northwest to southeast to maximize data collection efficiency. The starting point (designated x = 0 feet and y = 100 feet) was positioned north of the water treatment building and truck apron. Lines were spaced 10 feet apart and marked at each 50-foot interval.

The magnetometer was selected for this survey to detect buried ferrous, metallic objects. One magnetometer was used to record the diurnal variations of the earth's magnetic field. The second magnetometer was used as a roving magnetic gradiometer. During the survey, data were stored at one-half second intervals, along with time of measurement synchronized to the roving magnetometer clock. The base station magnetometer was downloaded to a computer at the end of the day to correct the roving magnetometer data for diurnal variations of the earth's magnetic field.

The Geonics EM-61 time domain electromagnetic metal detector system was utilized to sense all types of buried metallic objects. The EM-61 was operated in standard wheel mode, with data collection at 0.63-foot intervals along limes spaced 5 feet apart. The data collected by the EM-61 are expressed as millivolts (mv). Data were stored in an Omnidata Polycorder with associated line and position coordinates. The data were downloaded periodically to a computer for later processing.

The data from each instrument were entered into software packages to check for accuracy and to correct operator entry errors from field data collection. Each data set was entered into the Geosoft® Oasis Montaj data processing software for visual display of the data. Anomalous areas were checked using computer aided design (CAD) drawings and sketch maps to determine if the anomaly was associated with engineered features or anomalies caused by metallic debris or possible drums. The EM-61 data, magnetometer total field data, and magnetic gradient data were compared to one another to determine if coincident anomalies occurred.

The findings of the Phase III Area A EM and December 1998 survey work are presented in Section 4.0. Appendix B provides the geophysical results generated during both surveys.

2.2.3 Soil Gas Survey

The soil gas survey objective was to measure the concentrations of VOCs in soil gas around suspected source locations. Elevated VOC levels in soil gas could indicate soil and/or groundwater contaminated with VOCs. Information obtained from the soil gas survey was combined with data from the Phase I RI EM survey to better locate subsurface soil borings and test pits.

Soil gas sampling was performed using the hollow probe method. The probe and probe tip were driven into the ground to a specified depth using an electric hammer drill (Bosch hammer) or a power auger. The sampling depths ranged between 3 and 5 feet. After reaching the target sampling depth, the hollow probe was lifted to retract the probe adapter and expose the lowest 2 to 4 inches of soil at the bottom of the hole.

Polyethylene (PE) tubing with a threaded endpiece was tightened to the expendable point adapter at the bottom and connected at the surface to silicon tubing attached to a peristaltic pump. The peristaltic pump was used to purge the assembly before sampling and to extract air from the interstitial soil pore space. At some locations, at least two soil gas samples were extracted and analyzed. A Tedlar bag was connected to the sampling pump, filled with soil vapor, and sealed until analysis. The hollow probe and adapter assembly were removed and decontaminated between samples following standard protocol. A fresh length of PE tubing was used for each hole.

Soil gas analysis was performed in the on-base field trailer using a Hewlett Packard gas chromatograph (GC) equipped with a 30-meter, 0.25 mm inner-diameter (ID) capillary column that was coupled to a photoionization detector (PID) in-series with an electron capture detector (ECD). The GC was optimized for rapid (less than 7.5 minutes per run) analysis for acetone, 2-butanone, benzene, toluene, ethylbenzene, total xylenes, styrene, PCE, TCE, 1,1,1-TCA, carbon tetrachloride, chloroform, 1,1-dichloroethene, 1,2-DCE, 1,2-DCE, and 1,1-dichloroethane.

Calibration standards were diluted from certified methanolic standards into water using 40-ml VOC vials, leaving a 10-ml headspace. 400-milliter vapor aliquots were injected after standards were heated to 70°C for 5 minutes and shaken for 30 seconds. An initial 3-point calibration was performed and the practical quantitation limit (PQL) for each compound was established as one-half of the lowest concentration standard. The method achieved PQLs in the range of 0.03 to 0.3 ug/l for trichlorinated and tetrachlorinated compounds, followed by PQLs between 2 and 6 ug/l for compounds with carbon double bonds or aromatic rings, and PQLs between 15 and 50 ug/l for dichlorinated alkanes, acetone, and 2-butanone.

A continuing calibration standard was analyzed at the beginning of each day and repeated after every 15 injections. Subsequent continuing calibrations were assessed to verify stable system response; if response decreased by -60 percent or increased by +100 percent for more than one compound, then new calibration factors were required for all compounds. In the event of calibration error caused by systematic problems (e.g., syringe or detector malfunction), corrective action was taken and followed by a new standard injection and calibration factor update.

Analytical quality control procedures were followed for field blanks, field duplicates, syringe blanks, holding times, and decontamination. Duplicate samples and Tedlar bag blanks were collected at a frequency of one per 20 soil vapor samples. Syringe blanks were run for every 20 injections and after highly contaminated samples. High-level samples were followed by syringe cleaning and bake-out. Tedlar bags were flushed with three volumes of air between each use and were discarded if leaks were found. Syringe performance (plunger resistance, methanol dispensing, and injection spike size) was monitored to ensure the absence of leaks or blockage.

Syringes were repaired/replaced at the first symptom of malfunction. Analyses were required to be performed within 8 hours of sample collection.

Results were reported in units of aqueous micrograms per liter (ug/l), equivalent to the corresponding calibrated headspace concentration. For compounds quantifiable on both detectors, the detector having lower detection limits was consistently reported except when sample levels were above the linear range. A screening-level data validation was performed via electronic linking of sample and associated blank data files, after which results were incorporated into a database.

During Phase III, a comprehensive soil gas survey was performed at Area A according to the procedures detailed above. The survey grid covered the majority of EPIC features within Area A and consisted of up to 16 parallel, northwest-southeast-trending profile lines evenly spaced 25 feet apart (Figure 2-2). Soil gas samples were collected at 25- or 50-foot intervals across each profile line, except where surface or subsurface features (e.g., soil piles, berms, utilities, USTs) precluded the collection of soil gas samples.

The Area A soil gas survey results (including analytical data) were evaluated and plotted on color contour maps. The data were color contoured such that shades of orange, red, and purple represent high soil vapor data values. Shades of blue were used to represent background conditions as based upon this data set. Site surface features and suspected disposal location boundaries were used to make final interpretations regarding possible soil gas anomalies. An interpretation of the soil gas survey results is provided in Section 4.0 of this report. Appendix C contains the soil gas survey results from the Phase III RI investigation.

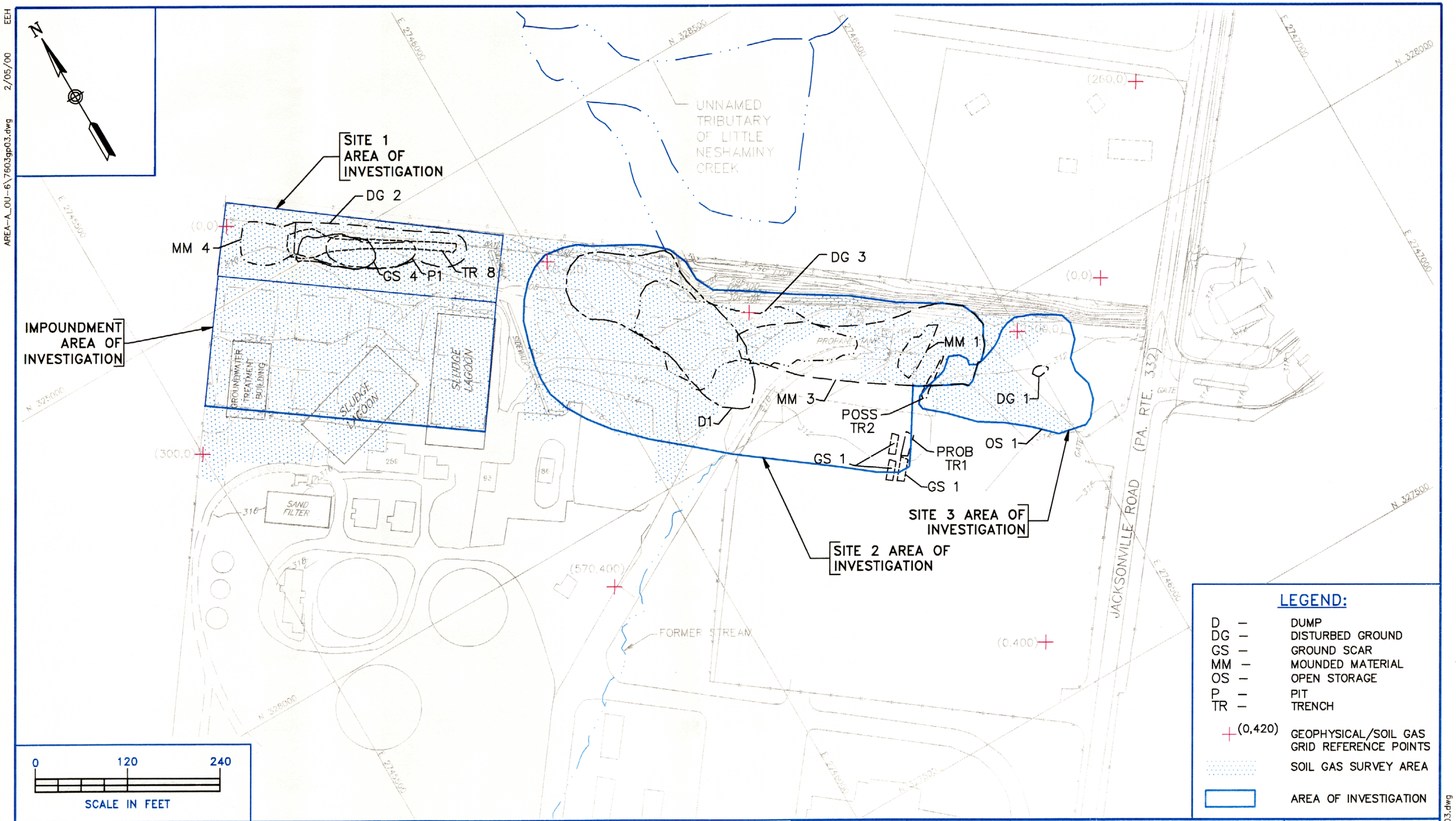
2.2.4 Surface Water/Sediment Sampling and Analysis

Surface water and sediment samples were collected from Area A during all three RI phases. Sample locations are shown in Figures 2-3 and 2-4. Hydrology characteristics for Area A are presented in Section 3.0.

Samples were taken from two locations during Phase I from an unnamed tributary of Little Neshaminy Creek located adjacent to Sites 2 and 3. One location was downstream of Sites 2 and 3 near the point where the stream leaves the base. The second location was upstream of the first location and Sites 2 and 3 and just downstream from the stream's origins from a storm water culvert under Jacksonville Road. Samples were analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) metals. Samples analyzed for TAL metals were not filtered.

Surface water and sediment samples were obtained from each of the Phase I locations during Phase II. An additional sediment sample was obtained during Phase II from an orange-colored leachate along the stream bank adjacent to Site 2, approximately 200 feet downstream from the culvert beneath Jacksonville Road. The Phase II samples were tested for TCL volatile and semivolatile organics, pesticides and PCBs, TAL

EEH 2/05/00 AREA-A_OU-6\7603gp03.dwg



LEGEND:

D –	DUMP
DG –	DISTURBED GROUND
GS –	GROUND SCAR
MM –	MOUNDED MATERIAL
OS –	OPEN STORAGE
P –	PIT
TR –	TRENCH
+ (0,420)	GEOPHYSICAL/SOIL GAS GRID REFERENCE POINTS
	SOIL GAS SURVEY AREA
	AREA OF INVESTIGATION

No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	OHM TRAILER AREA REMOVED.	LDL			

DRAWN BY EEH/LDL DATE 2/11/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

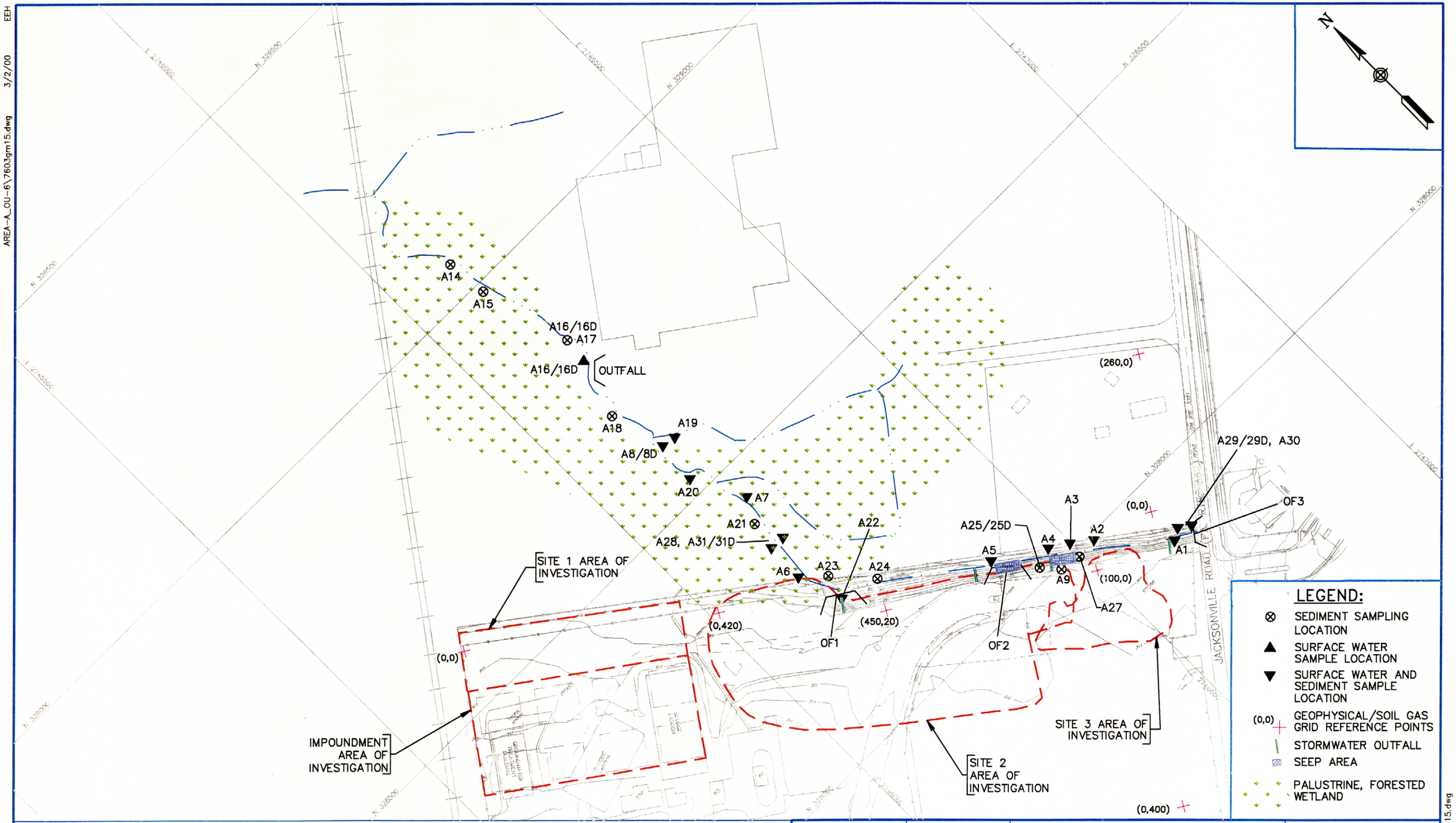
SOIL GAS SURVEY LAYOUT
AREA A
FORMER NAWC WARMINSTER
WARMINSTER, PA

CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY Jsa DATE 4/10/00
DRAWING NO. FIGURE 2-2 REV. 1

AREA-A_OU-6\7603gp03.dwg

442AB06Y

AREA-A_OU-6\7603gm15.dwg 3/2/00 EEH



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SCALE IN FEET

DRAWN BY	DATE
LDL\EEH	2/29/00
CHECKED BY	DATE
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SCALE AS NOTED	

Tetra Tech NUS, Inc.

SURFACE WATER/SEDIMENT SAMPLING LOCATIONS

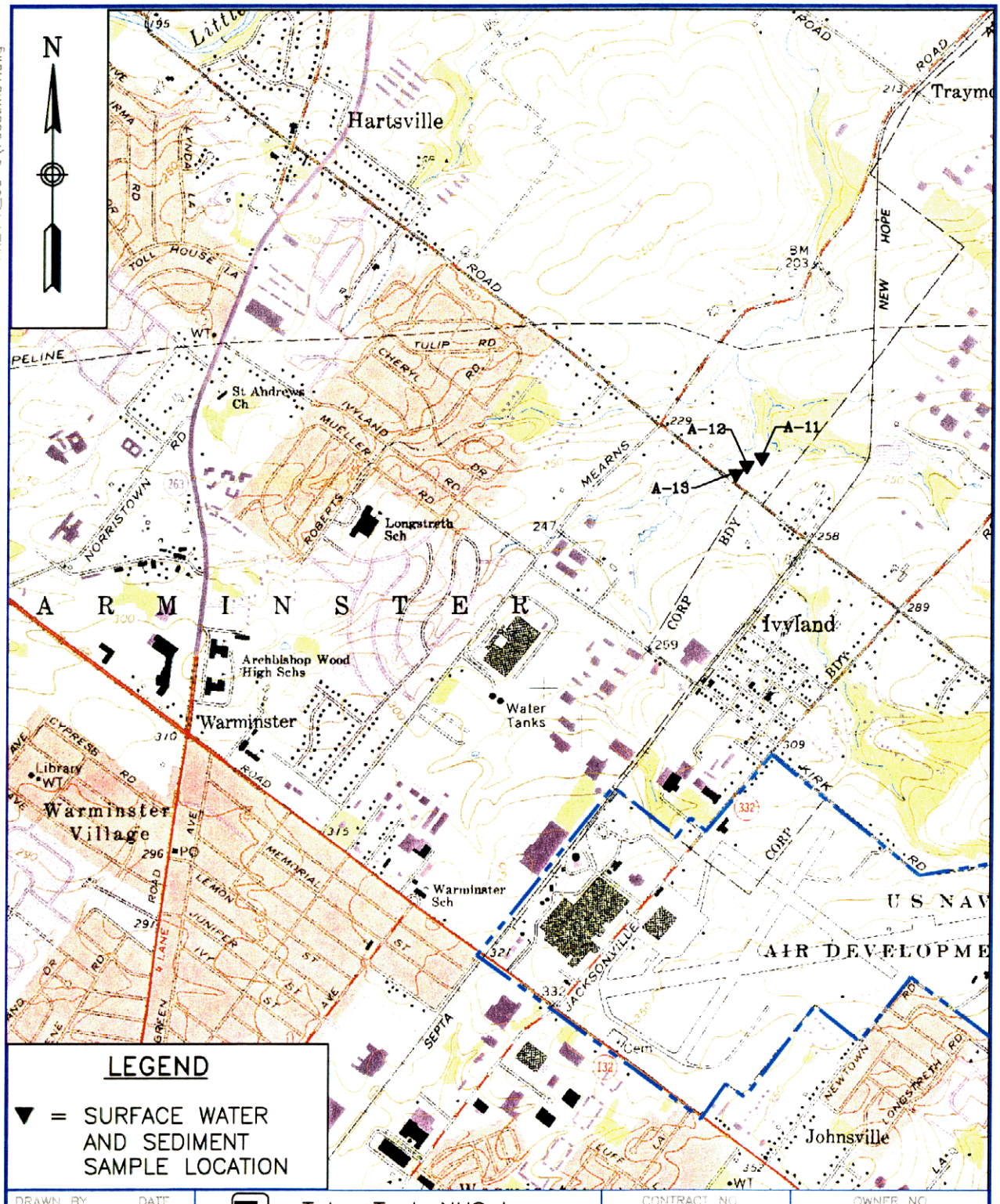
AREA A

FORMER NAWC WARMINSTER

WARMINSTER, PENNSYLVANIA

CONTRACT NO.	
7603	
OWNER NO. 0601	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-3	REV.

AREA-A_OU-6\7603gm15.dwg



LEGEND

▼ = SURFACE WATER AND SEDIMENT SAMPLE LOCATION

DRAWN BY LDL DATE 2/11/00	Tetra Tech NUS Inc.	CONTRACT NO. N62472-90-D-1298	OWNER NO. 7603
CHECKED BY DATE	AREA A FAR DOWNSTREAM SURFACE WATER/SEDIMENT SAMPLING LOCATIONS FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE 1"=2000'		DRAWING NO. FIGURE 2-4	REV.

SOURCE: (7.5 MINUTE SERIES) U.S.G.S. HATBORO, PA QUADRANGLE

AREA-A_OU-6\7603bm01.dwg

inorganics, and cyanide. The surface water samples were analyzed for both filtered and unfiltered TAL metals.

Surface water samples were collected at locations near Area A during Phase III. Two separate sampling events were made. The samples were analyzed for TCL VOCs, TCL semivolatile organics, TCL pesticides/PCBs, and TAL metals (both filtered and unfiltered). Sediment samples were obtained from nine locations near Area A during two sampling events as part of Phase III. The samples were analyzed for full TCL and TAL parameters.

Surface water and sediment analytical results are discussed in Sections 4.6 and 4.7, respectively. The analytical results are contained in Appendix A. Surface water samples were collected by directly filling a sample bottle. All surface water samples were transferred with a minimum amount of agitation into sample bottles specially prepared by the laboratory.

Vials for volatile organic analyses were kept free of any air bubbles. Volatile organic vials were filled before the remaining water sample bottles. Each sample was screened with a PID. Field measurements of temperature, pH, and specific conductivity were obtained for all surface water samples.

After a surface water sample was collected, the associated sediment sample was obtained slightly upstream of the surface water sampling point. The sediment was collected using a stainless-steel shovel or trowel. The volatile organic vial was filled first, leaving as little air space as possible. The remaining sediment sample bottles were then filled. Downstream samples were collected first, and samples from locations farthest upstream were collected last.

The surface water and sediment samples were preserved in coolers containing ice, following sampling. Sample logsheets including sample identification, date and time of collection, field measurements, analysis parameters, and other pertinent information were completed for each sample.

2.2.5 Surface Soil Sampling and Analysis

A surface soil sampling and analysis program was conducted during Phase III at Sites 1, 2, and 3 within Area A. Surface soil samples were analyzed for various parameters where physical characteristics and site history information suggested that these analyses should be performed. The parameters included full TCL organics, TAL metals, cyanide, and dioxins/furans. Analytical results for Area A surface soil samples are contained in Appendix A. Sample locations were selected based on the suspected source location, visual evidence of stained soils, and stressed vegetation.

Surface soil samples were taken from the uppermost soil horizon encountered after the overlying grass or sod layer was removed at each location with a shovel. The average depth of these samples was between 6 and 30 inches. All soil samples were placed directly into sample containers supplied by the laboratory using a stainless-steel sample trowel.

All soil samples were preserved in coolers containing ice following sampling. Sample logsheets including sample identification, date and time of collection, analysis parameters, and other pertinent information were completed for each sample.

2.2.5.1 Site 1

During Phase III, six surface soil samples were taken in the vicinity of Site 1 (Figure 2-5). Sample SS-01-06 was collected during a June 1992 sampling event. The Phase III RI samples were analyzed for TAL metals, TCL volatile organics, TCL semivolatile organics, TCL pesticides and PCBs, and dioxins/furans. The surface soil samples for Site 1 included locations within EPIC features DG2, TR8, GS4, P1, and MM4. Note that some samples were collected from more than one EPIC feature of concern within Site 1.

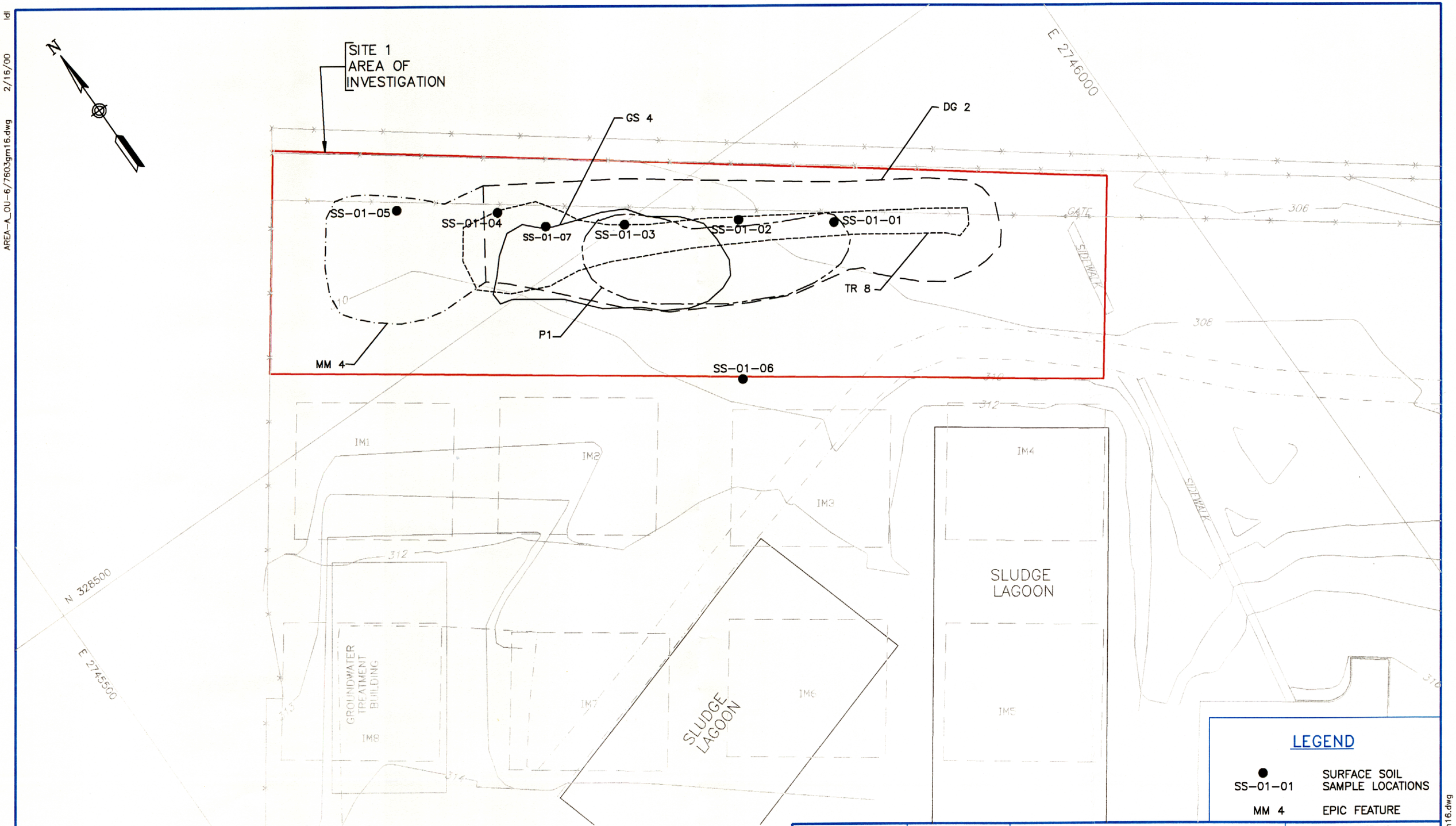
2.2.5.2 Site 2

During Phase III, 16 surface soil samples (and two duplicate samples) were taken in the vicinity of Site 2 (Figure 2-6). All samples were analyzed for TAL metals, TCL volatile organics, TCL semivolatile organics, and TCL pesticides and PCBs. The surface soil samples for Site 2 included locations within EPIC features MM3, DG3, D1, and MM1, as well as samples spaced throughout the surface disposal area.

Surface soil samples were also collected during supplemental investigations in July and October 1998. Surface soil verification samples in support of removal actions were collected in October, November, and December 1998.

2.2.5.3 Site 3

During Phase III, five surface soil samples were taken near Site 3. All samples were analyzed for TAL metals, TCL semivolatile organics, and TCL pesticides and PCBs. The surface soil samples for Site 3 included locations within EPIC features OS1 and DG1. Figure 2-7 details the Site 3 surface soil samples collected during the RI and surface soil verification samples collected in support of the soil removal action. These samples were collected in October and November 1999.



DRAWN BY LDL	DATE 2/16/00	Tetra Tech NUS, Inc.	SURFACE SOIL SAMPLE LOCATION MAP AREA A – SITE 1 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-5	REV.

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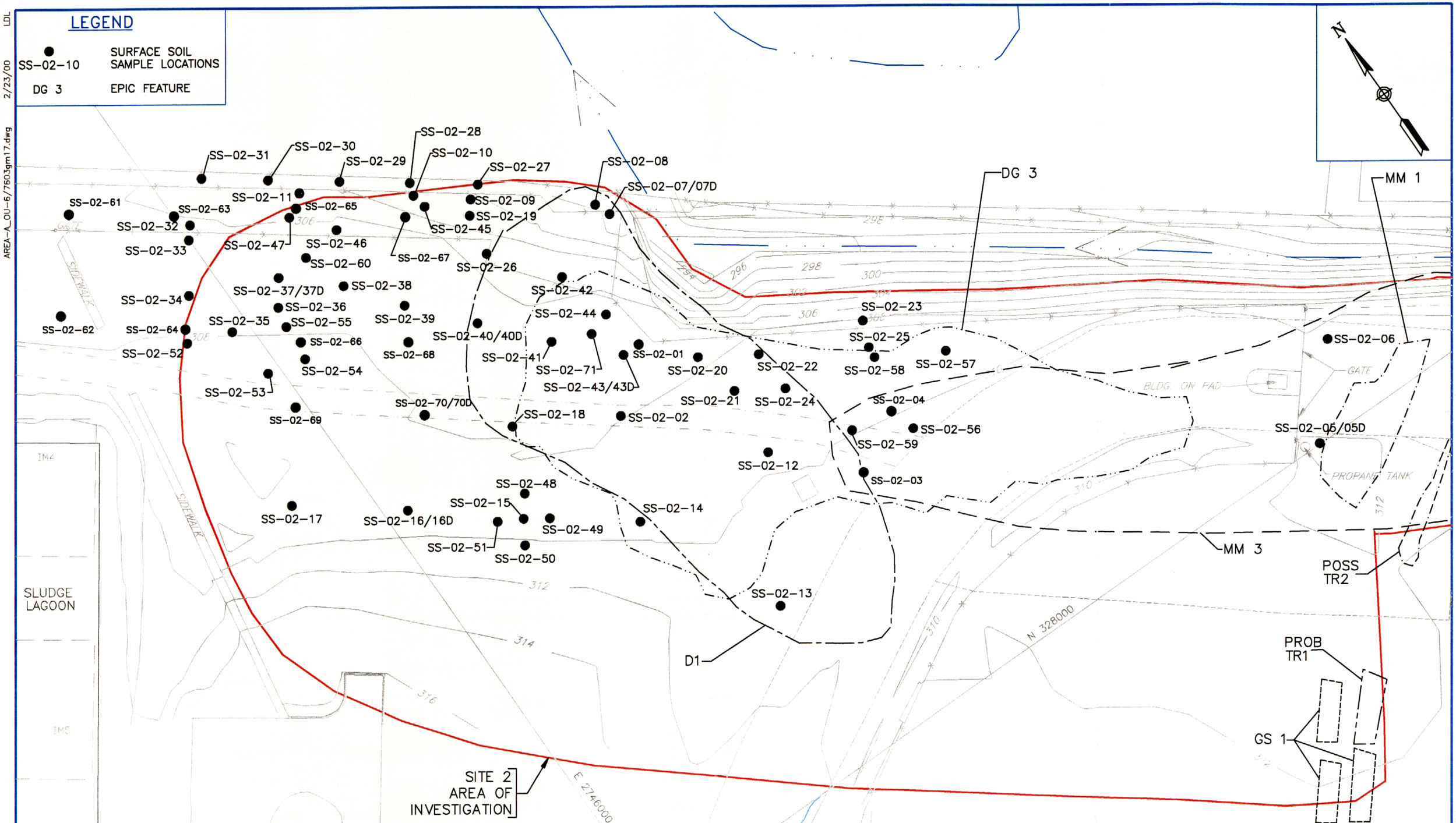

DRAWN BY LDL	DATE 2/23/00	Tetra Tech NUS, Inc.	SURFACE SOIL SAMPLE LOCATION MAP AREA A – SITE 2 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		CONTRACT NO. 7603
REVISED BY	DATE		OWNER NO. 0601
SCALE AS NOTED			APPROVED BY / DATE
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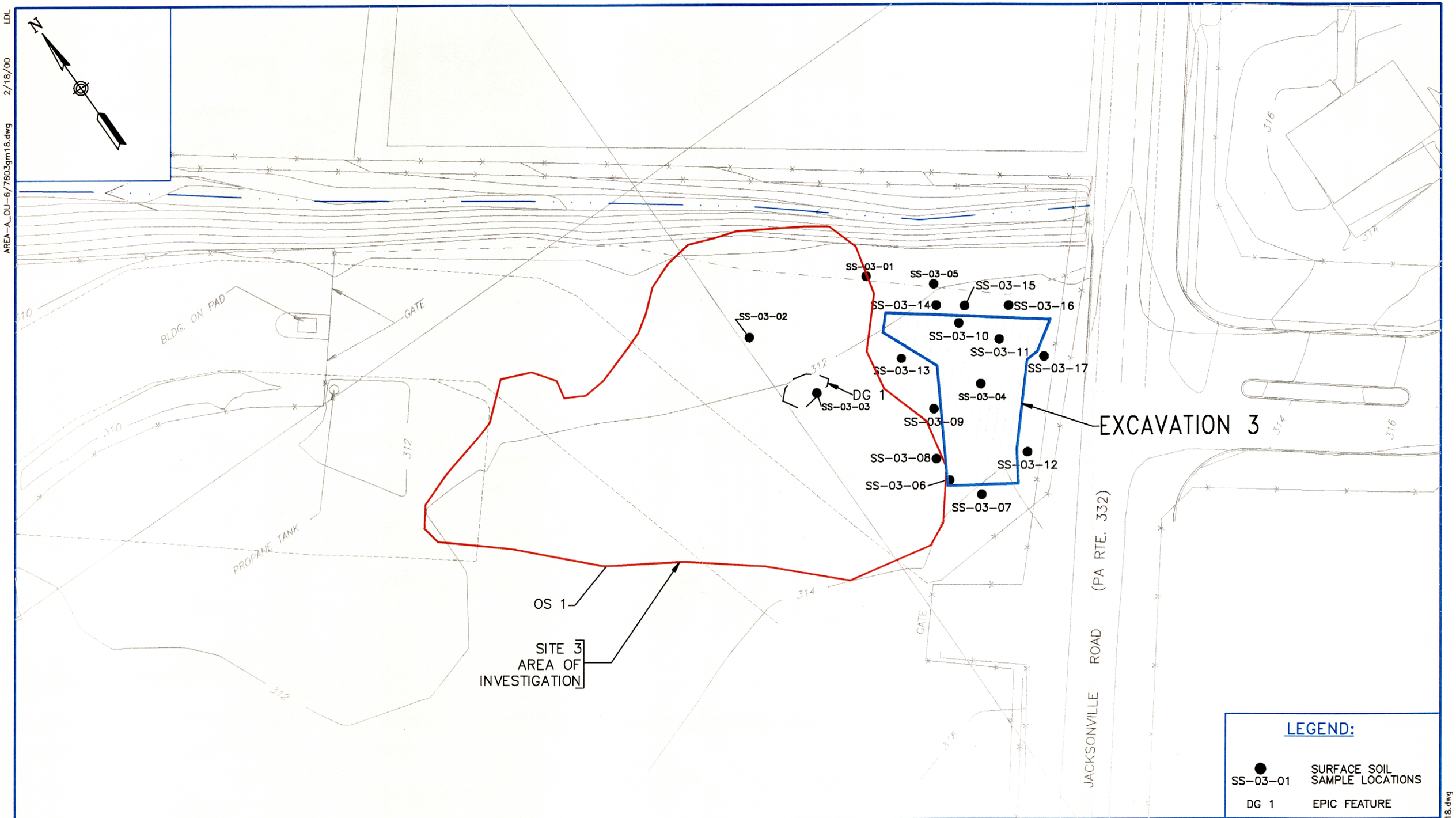

DRAWN BY LDL	DATE 2/18/00	Tetra Tech NUS, Inc.	SURFACE SOIL SAMPLE LOCATION MAP AREA A – SITE 3 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
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SCALE AS NOTED			

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY DATE
DRAWING NO. FIGURE 2-7 REV.

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2.2.6 Subsurface Soil Sampling and Analysis

Subsurface soil samples were obtained from several locations within Sites 2 and 3 during Phase II. One sample was taken from an area of high soil gas readings where waste material was detected in confirmation soil borings at Site 2. Two samples were taken from Site 3 in areas of high soil gas readings and/or detected waste materials.

During Phase III, subsurface soil samples were collected from all four areas of concern within Area A. Samples were obtained through soil borings, test pit excavations, hand augering, or trenching involved with the installation of piping for the OU-3 groundwater remedy. Subsurface soil sample locations were selected to correspond with EM and soil gas anomalies, suspected source areas, and approximate boundaries of EPIC features.

For Site 1, confirmation soil borings were also drilled to delineate the extent of an area of apparent buried waste materials. Test pits were excavated within EPIC feature TR2 to determine the nature of subsurface contamination at this location.

Soil borings were drilled and sampled to gather data about the extent, nature, and depth of contamination. The locations of the borings were determined after data gathered during the soil gas and EM surveys were reviewed. Most borings were completed by using a drilling rig with cleaned, decontaminated, hollow-stem augers. The cuttings were inspected for any waste material or VOCs as the auger brought them to the surface. Each boring was drilled until a significant amount of waste was encountered or to about 10 feet below ground surface, unless bedrock or some other impenetrable surface was encountered above 10 feet. The actual depth of each boring was specific to the suspected source being investigated. Upon completion, all boreholes were backfilled with the cuttings.

A PID was primarily utilized at each boring to detect any VOCs that may have been present. The PID has a detection limit of approximately 1 ppm. A majority of the soil borings were sampled continuously using a split-spoon sampler from the ground surface to the top of bedrock. Samples selected for laboratory analysis were based on elevated PID readings, evidence of wastes or buried materials (e.g., odors or staining), and other observations suggesting potential contamination if they were recorded. If no evidence of contamination was found, samples from just above the weathered bedrock interface were selected for analysis. Samples were analyzed for various analytes in accordance with the Phase III RI work plan and any addenda to the work plan.

Each boring was logged by a geologist. Information recorded by the geologist included lithology, waste materials encountered, PID concentrations, the depth at which waste was found, and any other pertinent

observations. This information was recorded on logs presented in Appendix D. Each boring location was determined in relation to a fixed point so that the exact location of the boring could be determined in the future should the need arise.

All field data were peer reviewed and checked for accuracy upon the completion of the boring survey.

The test pits were completed by the use of a backhoe to dig a trench approximately 3 feet wide. The lengths of the pits were about 20 feet. The target depth of each pit was approximately 8 feet or until bedrock or groundwater was encountered or to the maximum depth of wastes or fill material encountered.

The objectives of the test pits were to visually identify the extent and nature of waste material thought to be present in this area and to obtain soil/waste samples for chemical analysis. The test pit locations were selected after the Phase III soil gas survey and Phase I geophysical survey results were reviewed.

A PID was utilized at each test pit to detect any VOCs that may have been present. Each test pit was logged by a geologist. Information recorded by the geologist included lithology, waste encountered, volatile organic concentrations, the depth at which waste was found, and any other pertinent observations. Copies of test pit logs have been included in Appendix E.

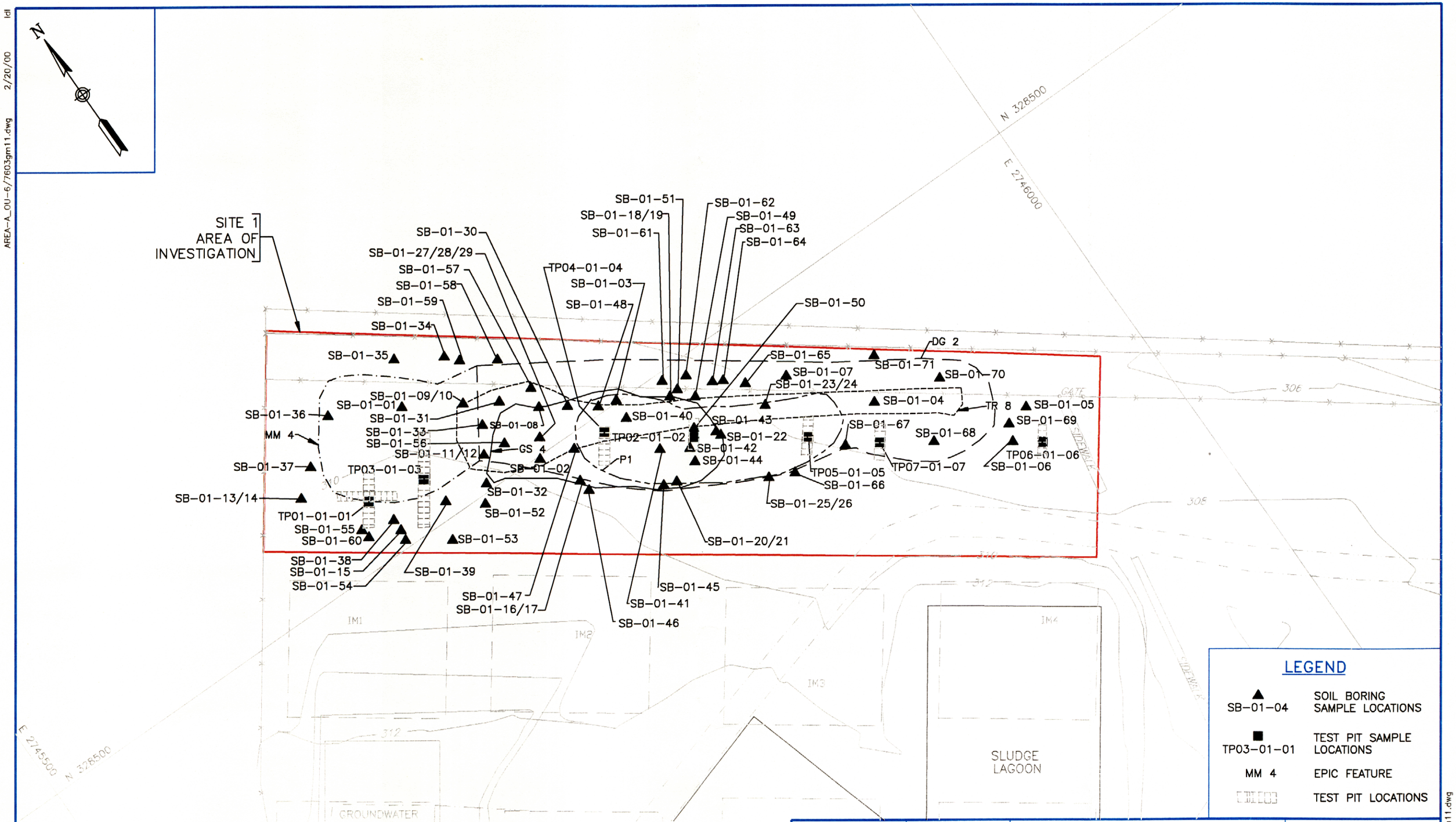
Upon completion, each test pit was backfilled with the excavated soil. The location of each test pit was confirmed in relation to a fixed point so that the location of the test pit could be determined exactly in the future should the need arise.

2.2.6.1 Site 1

A total of eight test pits, seven soil sample borings, and nine confirmation borings were excavated or drilled in the vicinity of Site 1 during Phase III. Figure 2-8 shows the subsurface soil sample locations for this site. Samples were collected from each EPIC feature near Site 1, as well as between the eastern end of Site 1 and the western end of Site 2.

All samples were analyzed for TCL volatile organics and TAL metals. Some test pit samples were analyzed for TCL semivolatile organics and PCBs, based on the surface soil results for that particular location. These analyses were also performed for other samples if the samples appeared to be potentially contaminated, based on visual observations and PID readings.

In addition, subsurface soil samples were collected during supplemental investigations at Site 1 in June and October 1998. Subsurface soil verification samples in support of removal actions were collected in September, October, and November 1998.



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Tetra Tech NUS, Inc.

TEST PIT AND SOIL BORING SAMPLE LOCATION MAP

AREA A – SITE 1

FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-8	REV.

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2.2.6.2 Site 2

The general location for Site 2 is bordered by the base access road to the east, Parking Lot No. 1 to the south, the base fence line to the north, and Site 3 to the east. For purposes of this report, Site 2 was divided into two separate portions for evaluating the nature and extent of contamination. The western portion of Site 2 lies between Site 1 and the impoundment area, the base fence line, the fuel storage area, and the base access road. The eastern portion is bordered by the base fence line, Site 3, Parking Lot No. 1, and the base access road.

One test pit and 34 sample borings were excavated or drilled within the western portion of Site 2. Samples were collected from each EPIC feature within the portion, as well as between the fuel storage area and the approximate boundaries of the EPIC features. Several subsurface soil samples were obtained along the excavated length of the groundwater transfer piping. Figure 2-9 displays the subsurface soil sample locations for Site 2.

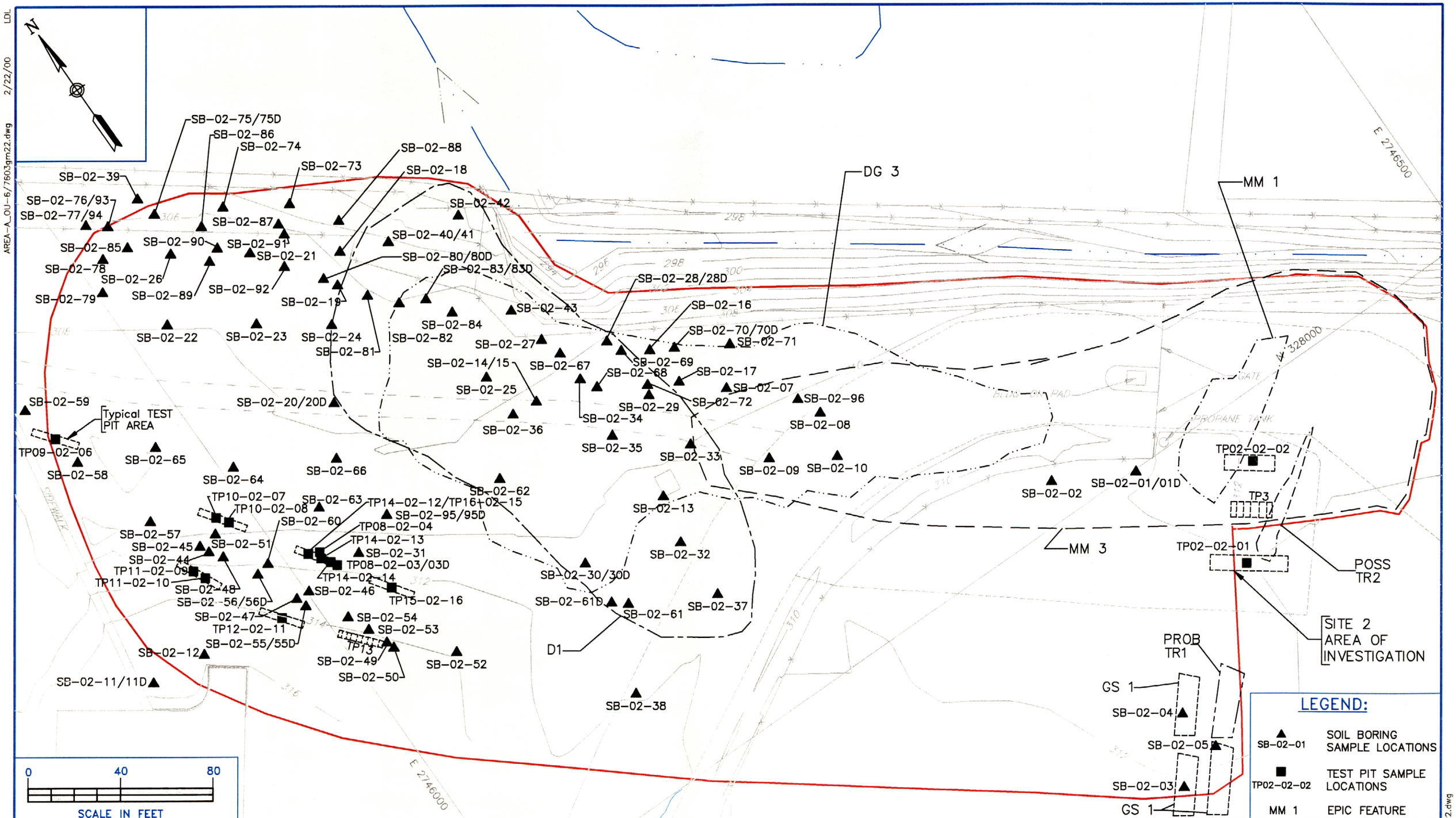
For the eastern portion of Site 2, three test pits and nine sample borings were excavated or drilled. Samples were obtained from each EPIC feature within the eastern portion, except for TR1. Samples were not collected from TR1 because the suspected trench at this location was determined to be an extension of the storm drain uncovered during the test pit work at TR2.

At least one sample was obtained from each boring within the vicinity of Site 2, and at least one sample was generally taken from each test pit. Samples were selected for analysis based on field screening for organics and visible evidence of potential contamination. If no evidence of potential contamination was found, samples were taken from directly above the deepest depth of non-native materials (if present) or the base of the boring/test pit.

All samples were analyzed for TCL volatile organics and TAL metals. About 50 percent of the samples were analyzed for TCL semivolatile organics and 25 percent for pesticides and PCBs. At least one sample from each feature of concern was analyzed for full TCL and TAL parameters. These analyses were performed on additional samples if the samples appeared to be potentially contaminated, based on visual observations and PID readings.

Subsurface soil samples were collected during several supplemental soil investigations at Site 2 in June, October, and November 1998. Subsurface soil verification samples in support of removal actions were collected in October 1998.

Seven test pits were excavated and ten soil samples were collected in the area north of the former jet fuel storage area and east of the eastern-most concrete lagoon at Site 2 in October 1999. The purpose of these



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/20/00	SAMPLE LOCATION NUMBER CORRECTED.	EEH			

DRAWN BY LDL DATE 2/22/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

TEST PIT AND SOIL BORING
SAMPLE LOCATION MAP
AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMNSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY DATE
DRAWING NO. FIGURE 2-9
REV. 1

LDL 2/22/00 AREA-A_OU-6/7603gm22.dwg

test pits was to further investigate the extent of contamination in this area. Soil samples were collected from the test-pits based upon field screening for organics and visible evidence of waste.

2.2.6.3 Site 3

During Phase III, three test pits and 10 sample borings were excavated or advanced near Site 3. Samples were collected from EPIC features OS1 and DG1, as well as between the approximate boundary of OS1 and Jacksonville Road. Several samples were taken during the trenching involved with bringing the groundwater transfer piping under this road. Figure 2-10 shows the subsurface soil samples locations for Site 3.

At least one sample was obtained from each boring within this area, and at least two samples were taken from each test pit (except for Test Pit No. 3). Samples were selected for analysis based on field screening for organics and visible evidence of potential contamination. If no evidence of potential contamination was found, samples were taken from directly above the deepest depth of non-native materials (if present) or the base of the boring/test pit.

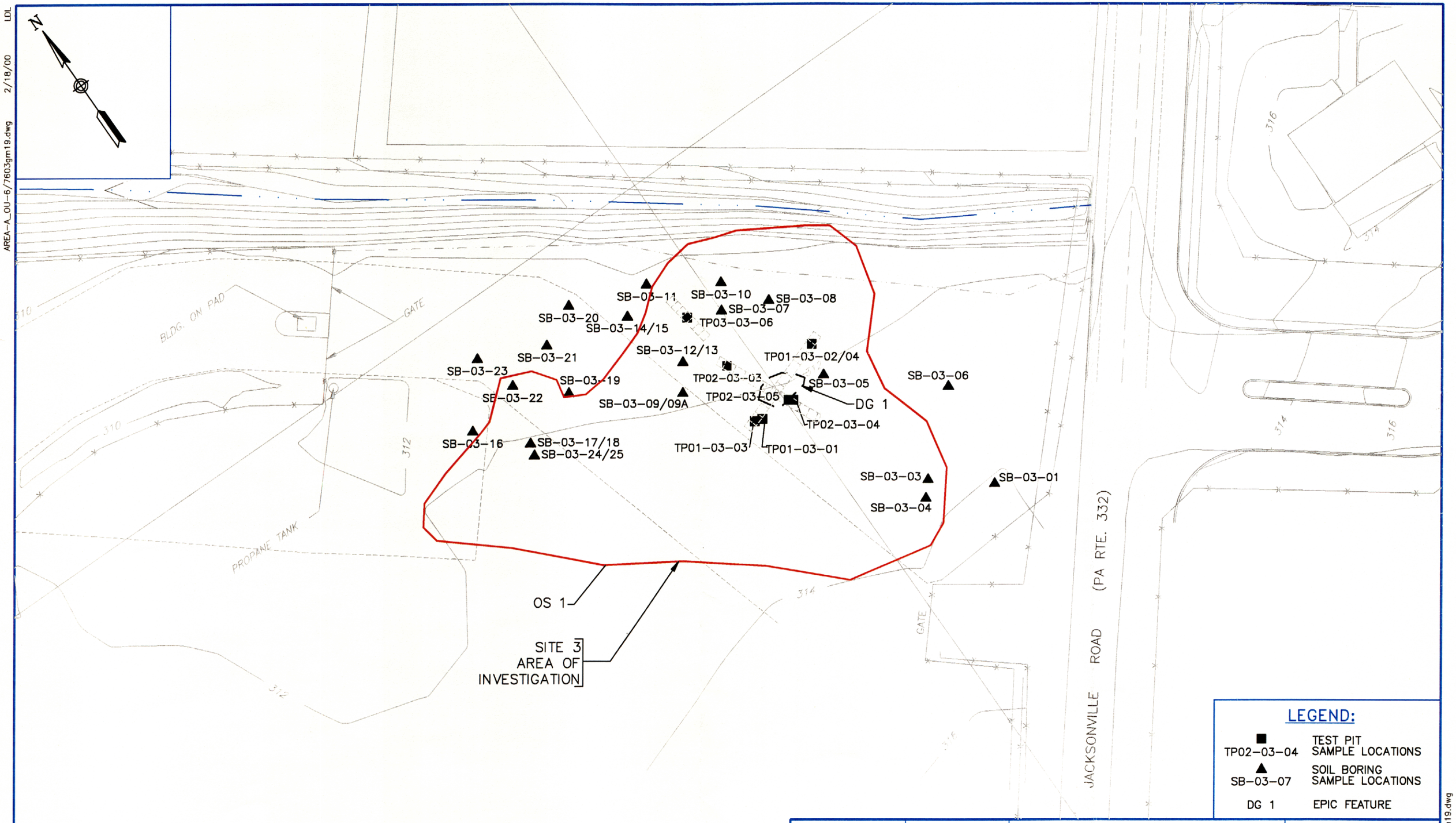
All samples were analyzed for TCL volatile organics and TAL metals. About 50 percent of the samples were analyzed for TCL semivolatile organics and 25 percent tested for pesticides and PCBs. At least one sample from each feature of concern was analyzed for full TCL and TAL parameters; however, all samples from the two test pits within DG1 and from boring SB-03-08 were analyzed for TCL semivolatile organics, pesticides, PCBs, and dioxin. These analyses were performed on additional samples if they appeared to be potentially contaminated, based on visual observations and PID readings.

Several subsurface soil samples were collected during supplemental investigations at Site 3 conducted in June and October 1998.

2.2.6.4 Impoundment Area

Subsurface soil samples were collected and analyzed from all eight impoundments during Phase III or during the construction of the OU-3 remedial action. To the extent possible, samples were obtained between the bottom of the former impoundments and the bedrock interface. At least five borings were advanced through each impoundment. Boring samples were also collected between the impoundment area and Site 1, between individual impoundments, and between the impoundment area and the wastewater treatment buildings (e.g., Buildings 20 and 259). A total of 70 borings were drilled in the vicinity of the impoundment area. Figure 2-11 displays the soil sample locations.

Two samples were sometimes obtained from each boring within this area. Soil boring samples were selected for analysis based on field screening for organics and visible evidence of potential contamination.



DRAWN BY LDL	DATE 3/14/00	Tetra Tech NUS, Inc.	TEST PIT AND SOIL BORING SAMPLE LOCATION MAP AREA A – SITE 3 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY DATE
DRAWING NO. FIGURE 2-10 REV.

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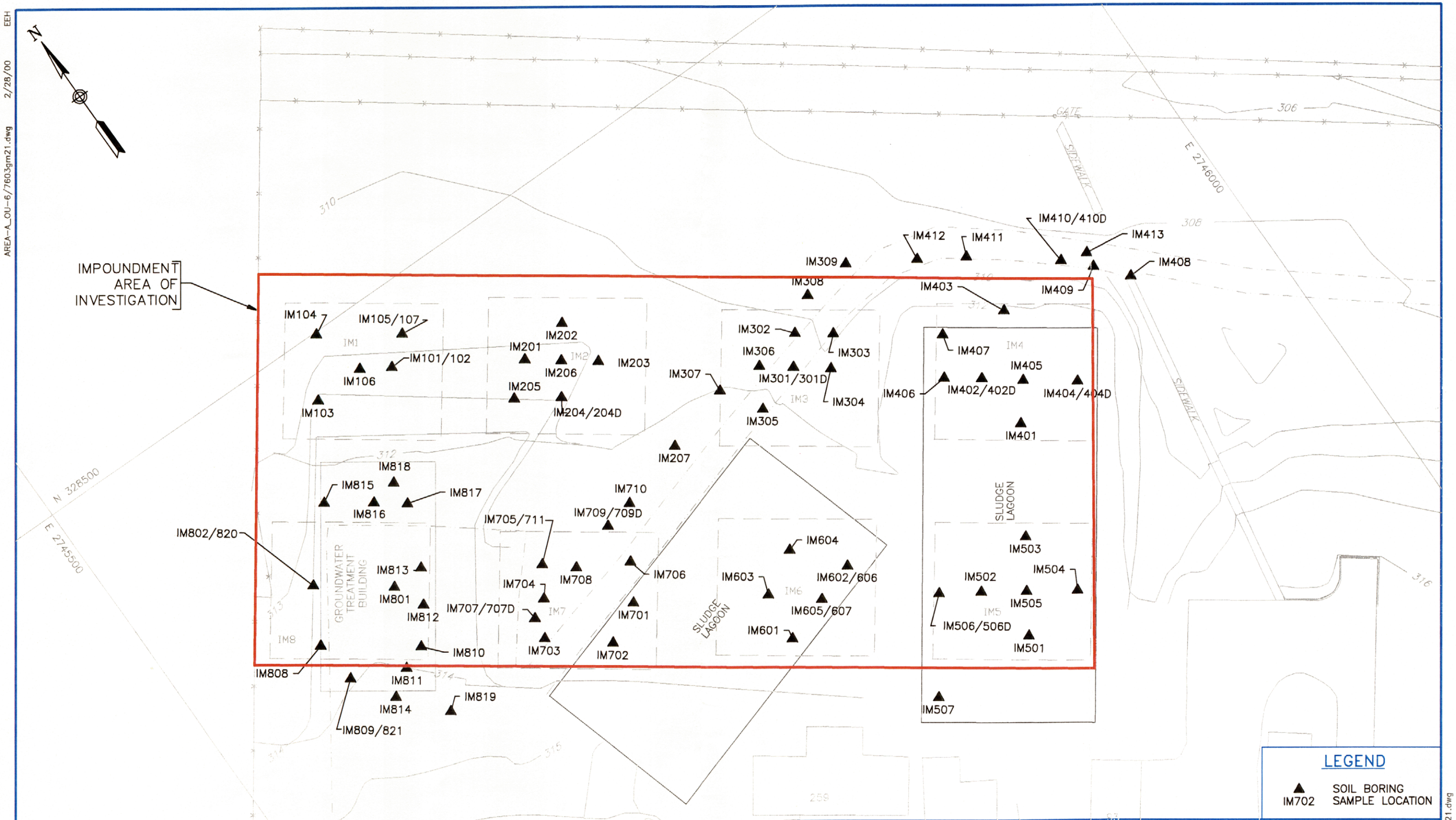

DRAWN BY	DATE
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CHECKED BY	DATE
REVISED BY	DATE
SCALE	
AS NOTED	

Tetra Tech NUS, Inc.

SOIL BORING SAMPLE LOCATION MAP
AREA A – IMPOUNDMENT AREA
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO.	
7603	
OWNER NO.	
0601	
APPROVED BY	DATE
DRAWING NO.	REV.
FIGURE 2–11	

AREA-A_OU-6/7603gm21.dwg 2/28/00 EEH

AREA-A_OU-6/7603gm21.dwg

If no evidence of potential contamination was found, samples were taken from directly above the deepest depth of waste materials (if present) or the bottom of the boring and from half the distance up from this sample depth to the ground surface.

All samples were analyzed for TCL volatile organics and TAL metals. About 50 percent of these samples were analyzed for hexavalent chromium. One sample from each impoundment was tested for TCL semivolatile organics, pesticides, and PCBs, except in the case of IM5. Samples taken from IM5 were tested for pesticides and PCBs. Other samples were analyzed for these parameters if the samples appeared to be potentially contaminated, based on visual observations and PID readings.

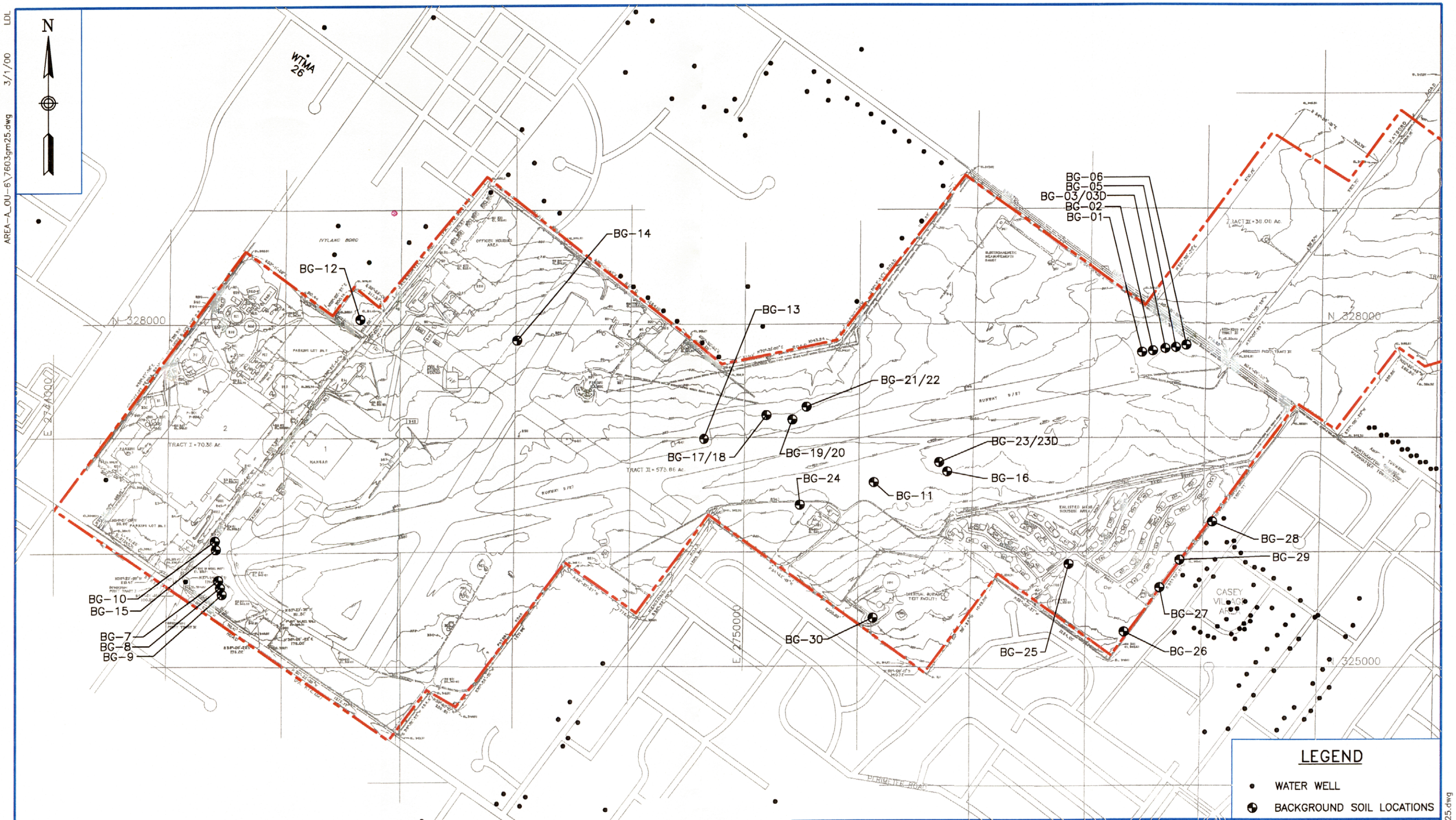
2.2.7 Background Soil Sampling

Background surface soil samples were collected during Phase III. A total of 10 surface soil samples were obtained from both ends of the main runway at the base. The background sample locations are shown in Figure 2-12. These samples were analyzed for TCL pesticides, PCBs, and TAL metals. Samples were not tested for TCL volatile organics or semivolatile organics because these substances were not considered to be naturally occurring or used for pest control/lawn maintenance purposes.

As part of this report, analytical results have also been included for the eight background subsurface soil samples that were taken during the Area B hydrogeologic investigation (HNUS, 1995b). These samples were collected from the soil/bedrock interface during the drilling of monitoring wells in this area. Only those subsurface soil samples from background monitoring well locations or from locations clearly outside suspected source boundaries within Area B were included in the analytical database for background soils. At most locations, hollow-stem augers fitted with a center plug were advanced to near the soil/bedrock interface (as determined during the installation of well casings). The plug was withdrawn, and the samples were obtained with a standard 2-inch by 24-inch, stainless-steel, split-spoon sampler. One sample was obtained with a hand auger. All samples were tested for TCL volatile organics and TAL metals. Samples were collected at depths ranging from 2.5 to 9 feet.

Analytical results were also incorporated for the background soil samples collected during the Site 4 EE/CA field investigation (HNUS, 1995d) and the Site 6 removal action investigation (B&R Environmental, 1996b). Background soil samples obtained during the Phase II RI (HNUS, 1992) and the associated results have also been included in the analytical database for background soil concentrations.

The occurrence and distribution of the analytical results of the RI background soil samples are shown in Table 2-2. The results from all background surface and subsurface soil samples were combined into one



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CHECKED BY	DATE			OWNER NO. 0601
REVISED BY	DATE			APPROVED BY / DATE
SCALE AS NOTED				DRAWING NO. FIGURE 2-12 / REV.

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TABLE 2-2
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN BACKGROUND SOIL
NAWC WARMINSTER, PENNSYLVANIA

Compound	Background Data					
	Frequency of Detection	Range of Positive Detections			Sampling Location of Maximum Concentration	Exposure Point Concentration
		Min		Max		
Aluminum	29/29	4780	-	18100	BG-12	15100
Antimony	1/21	13.6 J			BG-16	4.45
Arsenic	25/29	0.28	-	12.1 J	BG-11	11.6
Barium	25/27	34.1	-	225	BG-28	75.7
Beryllium	25/29	0.31	-	1.7 K	BG-23-D	0.878
Calcium	23/27	240	-	1910	BG-24	813
Chromium	29/29	7.9 J	-	35.3 JK	BG-12	21.6
Cobalt	25/28	1.6	-	22.1	BG-23-D	10.5
Copper	27/29	3.6 K	-	30.6	BG-29	14
Iron	29/29	6980	-	410500	BG-30	34800
Lead	29/29	1.6 J	-	96.5 J	BG-13	16.3
Magnesium	25/29	518	-	4960	BG-24	2260
Manganese	29/29	30.9	-	2010	BG-28	601
Mercury	1/27	0.37			BG-23	0.0483
Nickel	18/25	4.1 J	-	21.7 J	BG-23-D	11.7
Potassium	25/27	89.1	-	3050	BG-24	1060
Sodium	4/18	55.2	-	86.7	BG-25	86.7
Thallium	3/29	0.37	-	0.42	BG-23-D	0.42
Vanadium	29/29	15.4	-	45	BG-12	32.1
Zinc	25/27	9	-	60	BG-13	32.9
4,4'-DDD	1/20	16 JP			BG-12	3.05
4,4'-DDE	1/20	820			BG-12	17.4
4,4'-DDT	1/20	1440 JP			BG-12	25
Aroclor-1254	1/20	51			BG-13	43
1,4-Dichlorobenzene	1/11	43			BG-11	43
Benzo(b)fluoranthene	1/11	58 J			BG-13	58
Benzo(k)fluoranthene	1/11	46 J			BG-13	46
Bis(2-ethylhexyl)phthalate	1/11	50 J			BG-16	50
Chrysene	1/11	51 J			BG-13	51
Fluoranthene	1/11	92 J			BG-13	92
Phenanthrene	1/11	51 J			BG-13	51
Pyrene	1/11	100 J			BG-13	100
Acetone	4/18	8	-	12 J	BG-24	12
Chloromethane	2/19	3 J			BG-26	3
Toluene	3/19	2 J			BG-17	2

Notes:

Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
The determination of representative concentrations is based on comparison of maximum to the 95 % UCL, which is presented in a sepa
Frequency of detection refers to number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.

data set for data evaluation purposes and to compare background soil levels to site-related soil concentrations. Appendix F contains the analytical results for the background samples.

2.2.8 Background Stream Sampling

For Area A, background surface water and sediment samples were collected at several off-base locations that were considered unaffected by past site-related activities. Figure 2-13 details all of the background sample locations, except for surface water sample location A13, which is shown on Figure 2-4.

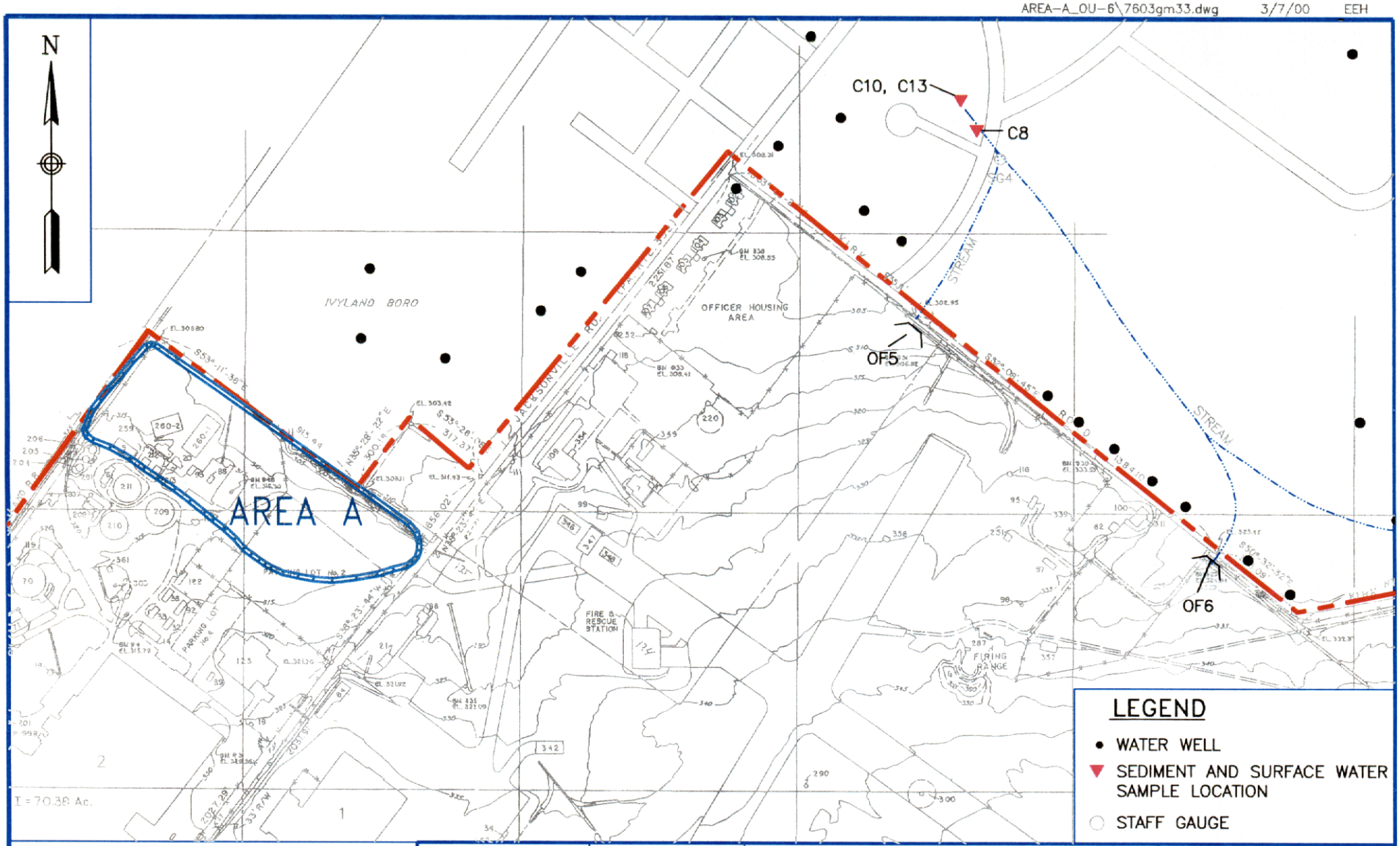
The background surface water samples were collected from locations C8, C10, C13 and A13. A background sediment sample was also collected at location C8. The sample locations, except for A13, were collected from a tributary of Little Neshaminy Creek, located northeast of Area A in a relatively non-urban setting and were considered to be representative of undisturbed surface water and sediment conditions. Sample location A13 is located several miles downstream of Area A along the unnamed tributary of Little Neshaminy Creek. No upstream samples could be collected for Area A.

The occurrence and distribution of the analytical results for the background surface water samples are presented in Table 2-3, total inorganics, and Table 2-4, dissolved inorganics. No organic compounds were detected in the background surface water samples. Table 2-5 presents the occurrence and distribution of inorganics in background sediment samples. The occurrence and distribution of organics in Area A background sediment samples are detailed in Table 2-6.

2.2.9 Wetlands Assessment

To supplement the Phase III RI, a wetlands assessment was performed in June 1994 to provide a qualitative appraisal of the plants and animals that could potentially be harmed by the inadvertent release of hazardous substances attributable to NAWC Warminster. As part of this assessment, the approximate wetland boundaries along the unnamed tributary of Little Neshaminy Creek downgradient from Area A were identified on USGS maps. Plants and animals associated with these wetlands were identified and used to characterize the wetlands according to procedures found in the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin, 1979). Wetlands were identified using the routine determination on-site inspection method (United States Army Corps of Engineers, 1987), including swamps, marshes, bogs, and similar areas. This method involves the use of USGS topographic maps, Soil Conservation Service soil surveys, aerial photographs, United States Fish and Wildlife Service National Wetlands Inventory (NWI) maps, and site-specific vegetation, soils, and hydrological information.

The results of the wetlands assessment are provided in Section 3.7 of this report. These results were used, along with the Phase I RI biological characterization and the analytical results from surface water and



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Tetra Tech NUS, Inc.

BACKGROUND SURFACE WATER/ SEDIMENT SAMPLE LOCATION MAP

AREA A

FORMER NAWC WARMINSTER

WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-13	REV.

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TAB. .-3

OCCURRENCE AND DISTRIBUTION OF TOTAL INORGANICS IN SURFACE WATER IN BACKGROUND - AREA A

WARMINSTER, PENNSYLVANIA

(ug/L)

	BACKGROUND				
SUBSTANCE	MEAN	STATISTICAL DISTRIBUTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
ALUMINUM	303.00	NONPARAMETRIC DIST	1 / 2	106 - 106	106
BARIUM	126.57	NORMAL OVER LOGNORMAL	2 / 3	60 - 69.7	69.7
CADMIUM	2	NONPARAMETRIC DIST	1 / 4	4	4
CALCIUM	17867	NONPARAMETRIC DIST	3 / 3	15900 - 19400	19400
IRON	660.00	NONPARAMETRIC DIST	2 / 2	630 - 690	690
MAGNESIUM	6960	NONPARAMETRIC DIST	3 / 3	6590 - 7240	7240
MANGANESE	48.17	NONPARAMETRIC DIST	2 / 3	11.5 - 83	83
POTASSIUM	1420	NONPARAMETRIC DIST	3 / 3	1130 - 1700	1700
SODIUM	11713	NONPARAMETRIC DIST	3 / 3	8980 - 16200	16200

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 2-4

OCCURRENCE AND DISTRIBUTION OF DISSOLVED INORGANICS IN SURFACE WATER IN BACKGROUND - AREA A

WARMINSTER, PENNSYLVANIA

(ug/L)

	BACKGROUND				
SUBSTANCE	MEAN	STATISTICAL DISTRIBUTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
BARIUM	62.30	NONPARAMETRIC DIST	3 / 3	53 - 74.5	74.50
CALCIUM	18800.00	NONPARAMETRIC DIST	3 / 3	15200 - 22100	22100
COPPER	7.47	NONPARAMETRIC DIST	2 / 3	5.6 - 14.8	14.80
LEAD	0.67	NONPARAMETRIC DIST	1 / 3	1	1
MAGNESIUM	7253.33	NONPARAMETRIC DIST	3 / 3	6230 - 7920	7920
MANGANESE	49.00	NONPARAMETRIC DIST	2 / 2	25 - 73	73
POTASSIUM	1356.67	NONPARAMETRIC DIST	3 / 3	1290 - 1470	1470
SODIUM	12456.67	NORMAL	3 / 3	9440 - 18400	18400
ZINC	6.25	NONPARAMETRIC DIST	1 / 2	10.5 - 10.5	10.50

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TAB. 5

OCURRENCE AND DISTRIBUTION OF INORGANICS IN BACKGROUND SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA
PAGE 1 OF 1

Substance	Background Data			
	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration
ALUMINUM	4/4	2920 - 5420	A13-SD	5,420
ARSENIC	2/3	2.3 - 2.8	C8-SD	2.80
BARIUM	3/4	31.4 - 65.9	A13-SD	65.9
BERYLLIUM	3/4	0.52 - 0.62	C8-SD	0.62
CALCIUM	3/4	893 - 1290	C13-SD	1,290
CHROMIUM	4/4	7.7 - 11.7	C13-SD	11.7
COBALT	1/3	4.4	C10-SD	4.40
COPPER	3/4	5.4 - 8.2	A13-SD	8.20
IRON	4/4	5800 - 11200	C13-SD	11,098
LEAD	3/4	9.8 - 24.6	C13-SD	24.6
MAGNESIUM	3/4	1040 - 1320	C13-SD	1,320
MANGANESE	4/4	144 - 289	A13-SD	288
NICKEL	3/4	4.4 - 6.3	A13-SD	6.3
POTASSIUM	3/4	288 - 492	A13-SD	492
SODIUM	1/3	340	C13-SD	340
VANADIUM	4/4	10.3 - 13.6	C13-SD	13.6
ZINC	4/4	32.9 - 57.2	C13-SD	57.2

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is pr
Frequency of detection refers to the number of times compound was detected among all samples versus total numbe
Number of samples may vary based on the number of usable results.

TABLE 2-6

OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SEDIMENT IN BACKGROUND - AREA A

WARMINSTER, PENNSYLVANIA

(ug/kg)

SUBSTANCE	BACKGROUND				
	MEAN	STATISTICAL DISTRIBUTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
4,4'-DDT	3.50	NONPARAMETRIC DIST	1 / 2	4.9	4.9
AROCLOR-1254	55	NONPARAMETRIC DIST	1 / 3	24	24
ENDRIN	6.53	NONPARAMETRIC DIST	1 / 3	5.5	5.50
4-METHYLPHENOL	970	NONPARAMETRIC DIST	1 / 3	200	200
ANTHRACENE	897.33	NONPARAMETRIC DIST	2 / 3	95 - 97	97
BENZO(A)ANTHRACENE	290	NONPARAMETRIC DIST	3 / 3	210 - 380	380
BENZO(A)PYRENE	1107	NONPARAMETRIC DIST	2 / 3	260 - 560	560
BENZO(B)FLUORANTHENE	1217	NONPARAMETRIC DIST	2 / 3	320 - 830	830
BENZO(G,H,I)PERYLENE	1007	NONPARAMETRIC DIST	2 / 3	150 - 370	370
BENZO(K)FLUORANTHENE	997	NONPARAMETRIC DIST	2 / 3	200 - 290	290
CARBAZOLE	225	NONPARAMETRIC DIST	1 / 2	240	240
CHRYSENE	373	NONPARAMETRIC DIST	3 / 3	190 - 590	590
DI-N-BUTYL PHTHALATE	59	NONPARAMETRIC DIST	1 / 3	59	59
DIBENZO(A,H)ANTHRACENE	924.33	NONPARAMETRIC DIST	1 / 3	53	53
FLUORANTHENE	776.67	NONPARAMETRIC DIST	3 / 3	380 - 1400	1400
FLUORENE	919	NONPARAMETRIC DIST	1 / 3	47	47
INDENO(1,2,3-CD)PYRENE	1003	NONPARAMETRIC DIST	2 / 3	190 - 320	320
PYRENE	560	NONPARAMETRIC DIST	3 / 3	330 - 760	760
2-BUTANONE	7.83	NONPARAMETRIC DIST	1 / 3	9	9
TOLUENE	7.75	NONPARAMETRIC DIST	1 / 4	4	4

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

sediment sampling, to help complete the ecological risk assessment for NAWC Warminster. The biological characterization was completed on a qualitative, descriptive level, and it did not involve sampling procedures for area biota.

2.2.10 Surveying

Surveying was conducted as part of the Phase III RI in order to determine the exact location of the grids used for the soil gas survey and to better locate soil sample locations. At least two corners of each survey grid were surveyed for horizontal location or tied into existing site structures (including existing surveyed monitoring well locations) to provide reference points for locating the entire grid.

The horizontal survey utilized survey traverse control established in 1985, 1986, and 1987 during aerial mapping of the entire base and field survey location of all utilities. All coordinates are based on the Pennsylvania State Plane Coordinate System (South Zone, 1927 Datum). The error of closure of all horizontal survey work is better than 1 part in 10,000. All elevations are based on the North American Vertical Datum of 1929.

To determine the survey locations, three horizontal traverses, which began and ended on property corner monuments, were conducted. At least three corner monuments were tied on each traverse. All three traverses closed relative to the Survey Map entitled "Survey Map, U.S. Naval Air Development Center, Warminster Township, Bucks County, Pennsylvania" with a tolerance better than the proposed standard of 1 part in 10,000. Tabulated survey data from Phase III are provided in Appendix G.

2.3 ANALYTICAL PROCEDURES AND DATA VALIDATION

2.3.1 Analytical Procedures

During Phase I, samples were analyzed as specified by EPA's Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Third Edition. Samples were analyzed for TCL volatile organic compounds, TCL semivolatile organic compounds, TCL pesticides/PCBs, and TAL metals. Samples analyzed for TAL metals were not filtered. Data packages were submitted under Naval Energy and Environmental Support Activity (NEESA) Level C requirements.

For Phase II, a subcontracted NEESA-approved laboratory analyzed aqueous and solid matrix samples collected at NAWC Warminster for full TCL organics, TAL inorganics, cyanide, total petroleum hydrocarbons TPH, BTEX, and a variety of physical-chemical parameters (e.g., hardness, alkalinity, total suspended solids, chlorides, grain size). Data packages were submitted under NEESA Level D requirements.

During Phase III, several laboratories analyzed aqueous and solid matrix samples for full TCL organics, TAL inorganics, cyanide, grain size, TOC, and dioxins/furans. The most frequently used analytical methods selected for these analyses are presented in Table 2-5. Most data packages were submitted under Naval Facilities Engineering Service Center (NFESC) Level D requirements. Some data packages were submitted under reduced requirements for laboratory deliverables, particularly for quick-turnaround results associated with the Area A trench excavation work.

2.3.2 Data Validation

The data validation process serves three basic functions:

- An independent quality assurance check of the accuracy of the laboratory results.
- A means of evaluating laboratory performance and determining the impact of noncompliances to the data.
- Through the use of data qualifiers, it lends interpretative guidance as to the proper usage and limitations of the data.

The validation process is a systematic review and evaluation of the analytical data conducted according to applicable and relevant quality control criteria, including

- EPA's National Functional Guidelines for Evaluating Laboratory Analyses
- Method-specific quality control criteria
- Navy-specified technical guidelines
- TtNUS data validation formats and standard operating procedures

Organic data were evaluated based on

- Data completeness
- Holding times
- Gas chromatograph/mass spectrometers(GC/MS) tuning and mass calibration (when applicable)
- Initial and continuing calibrations
- Laboratory blank analyses
- Field blank analyses (when applicable)
- Internal standards performance
- Surrogate spike recoveries
- Matrix spike/matrix spike duplicate results

- Field duplicate precision (when applicable)
- Compound detection limits
- Compound identification
- Compound quantitation
- Tentatively identified compound (TIC) evaluation (when applicable)

Inorganic data were evaluated on the basis of

- Data completeness
- Holding times
- Initial and continuing calibrations
- Contract required detection limit (CRDL) standard analyses
- Laboratory and field blank analyses (when applicable)
- Matrix spike results
- Laboratory control sample results and duplicate analyses
- Field duplicate precision (when applicable)
- ICP interference check sample results
- ICP serial dilution analyses
- Furnace atomic absorption results
- Analyte detection limits
- Analyte quantitation

Data validation reports were generated from these results and conclusions drawn from the validation process described above. The specific format of the data validation report varies with the applicable protocol, but all reports address the following:

- Explanation of the findings of the data evaluation process, giving interpretations of actions taken on the data and limits of data usability.

- Presentation of the qualified analytical results.

- A validation worksheet and/or support documentation section depicting the problem areas and noncompliances addressed in the data validation memoranda and supporting the validation actions taken.

The formal data validation process and the supporting documentation is essential for the following reasons:

- To ensure the accuracy and integrity of the analytical data

- To ensure the defensibility of the data
- To provide a platform from which remediation/risk assessment issues can be addressed

2.4 DATA EVALUATION

This section presents various aspects of data evaluation including determining representative concentrations, data reduction and tabulation, and a comparison of data to screening criteria.

2.4.1 Representative Concentrations

To support the data evaluation process, a representative concentration for each chemical in each medium identified at Areas A was calculated using the latest risk assessment guidance from EPA (EPA, 1989a; EPA, 1992). Pre-removal conditions were evaluated. As discussed later, Exposure Point Concentrations were calculated for post-removal conditions. Usability of results is discussed below.

The validated data were used to calculate representative concentrations. For chemicals with at least one positive detection, non-detects were assumed to be one-half the detection limit (sample quantitation limit). Rejected values (R) were eliminated from further consideration. As per EPA Region III guidance, values attributed to blank contamination (B) were eliminated from further consideration. Estimated and biased values (J, K, L) were used at the reported value.

Duplicate samples were averaged together and considered as one result. For duplicates, where one result was positive and the other result was a non-detect, the problem of calculating an average result arose whenever half the detection limit exceeded the positive result. It was considered undesirable for the average to exceed the positive result; therefore, the positive result was used to represent the non-detect in such cases.

Phase I data are from the SMC report (SMC Martin, 1991). Phase II and Phase III data were collected by B&R Environmental. The data were regarded as one set of data for each individual site (surface soil and subsurface soil) or area (surface water and sediment) regardless of the RI phase in which the data were collected. For surface water and sediment samples, there were cases where the same approximate location had been sampled during different phases; therefore, the results were simply treated as individual samples indicating media contamination over time and were not treated as duplicates.

The calculation of the representative concentration is a two-step process. First, the distribution of the data must be determined as discussed in the preceding section. Then, based on the distribution of the data, a representative concentration is either calculated or selected.

Several important points are associated with distribution of the data:

- The distribution of a data set is determined using a Shapiro-Wilk test.
- The distributions are classified as either lognormal, normal, or unknown.
- Environmental data are usually determined to be lognormally distributed (default).
- If the data are not determined to be either a lognormal or normal distribution, they are classified as an unknown distribution and a lognormal distribution is assumed.

If the data are considered to be lognormally distributed, then the standard deviation of the log-transformed sample set must be determined, as follows:

$$S = [\Sigma (X_i - X_m)^2/n-1]^{0.5}$$

where:
- S = Standard deviation of the log-transformed data
- X_i = Individual sample value (log-transformed)
- X_m = Arithmetic mean of the log-transformed n samples
- n = Number of samples

The one-sided upper 95 percent confidence limit (UCL_{LOG}) is then calculated as follows:

$$UCL_{LOG} = \exp[(X_m + (0.5S^2) + SH)/(n-1)^{0.5}]$$

where:
- exp = exponential function (inverse of the neutral log)
- X_m = Arithmetic mean of the log-transformed data
- H = H-statistic (e.g., from table published in Gilbert, 1987)
- S = Standard deviation of the log-transformed data
- n = Number of samples

The representative concentration is then selected as the lesser value of the one-sided 95 percent UCL and the maximum positive value in the data set.

If the data are determined to be normally distributed, then the standard deviation of the sample set is used to calculate the one-sided 95 percent UCL as follows:

First, the standard deviation of the sample set must be determined, as follows:

$$S = [\sum (X_i - X_m)_2/(n-1)]^{0.5}$$

where: S = Standard deviation

X_i = Individual sample value

X_m = Arithmetic mean for the n samples

n = Number of samples

The one-sided upper 95 percent confidence limit (UCL_{NOR}) is then calculated as follows:

$$UCL_{NOR} = X_m + t(S/n^{0.5})$$

where: X_m = Arithmetic mean

t = One-sided t distribution factor

S = Standard deviation

n = Number of samples

For small sample sets or sample sets in which all positive results equal less than one-half the detection limit, the UCL can exceed the maximum detected concentration. In these cases, the maximum concentration was selected as the representative concentration.

The calculation of the representative concentration is a two-step process. First, the standard deviation of the sample set must be determined, as follows:

$$S = \text{sqrt}\,[\text{sum}(Xi-Xm)^2/(n-1)]$$

where: S = Standard deviation

X_i = Individual sample value

X_m = Arithmetic mean for the n samples

n = Number of samples

The two-sided upper 95 percent confidence limit (UCL) is then calculated as follows:

$$UCL = Xm + tS/\text{sqrt}\,n$$

where: X_m = Arithmetic mean

t = Two-sided t distribution factor

S = Standard deviation

n = Number of samples

The representative concentration is then selected as the lesser value of the one-sided 95 percent UCL and the maximum positive value in the data set. Upper confidence limits (UCLs) for all contaminants, from which the representative concentrations are derived, are presented in the site-specific sections of this report.

2.4.2 Data Reduction/Tabulation

The data sets were reduced by selected only those chemicals with positive detections at a suspected source concern. The results of sampling analysis at a site or area were summarized in an occurrence and distribution table. These tables contain representative concentrations (See Section 2.4.1) and summary statistics including frequency of detection, range of positive detection, and statistical distribution of the data sets. Background occurrence and distribution tables contain for each chemical a mean, statistical distribution of the data set, frequency of detection, range of positive detection, and representative concentration. Site or area occurrence and distribution tables contain for each chemical a representative concentration for background (if applicable) and frequency of detection, range of positive detection, statistical distribution, and a representative concentration for site- or area-related data.

Background samples for surface and subsurface soils were collected from various locations at NAWC Warminster (Figure 2-12) that were considered unaffected by past site-related activities. All surface and subsurface background samples were pooled together and used as background for any site-specific surface or subsurface data set. The background occurrence and distribution for soils are presented in Table 2-2.

For Area A, surface water and sediment samples were collected in off-base locations that were considered unaffected by past site-related activities. See Figure 2-13 for surface water and sediment sampling locations. These locations were used as the background sample set for Area A surface water and sediment data sets.

The background occurrence and distribution tables for surface water at Area A are shown in Tables 2-3 (total inorganics) and 2-4 (dissolved inorganics). No organic chemicals were detected in background surface water for Area A. The background occurrence and distribution tables for sediment at Area A are shown in Tables 2-5 (inorganics) and 2-6 (organics).

2.4.3 Comparison of Data to Screening Criteria

Each site-related soil data set was compared to appropriate screening criteria for the purposes of identifying areas of soil contamination, identifying possible sources or portions of sources where response actions may be necessary, and identifying sites that may require a risk assessment. The screening criteria used for these comparisons were from federal and state sources. Federal sources included EPA Region III Risk Based Concentration (RBC) Tables (EPA, 1996a) and Soil Screening Levels (SSLs) (EPA, 1999b). Commonwealth of Pennsylvania criteria were obtained from the Statewide Health Standard Tables, Subchapter C, Section 250.312 of the PA Land Recycling Program Regulations. This includes the medium-specific concentrations (MSCs) for soils. For purposes of this report, industrial and/or non-residential exposure scenario criteria were used. The future intended use of sites 1, 2, 3, and the Impoundment Area is industrial. The results of these comparisons are in the form of appropriate tables and figures provided in the site-specific sections of this report. If a chemical had a detection greater than the most stringent screening criterion and not considered to be in the range of background range of detection (inorganics only), this result was shown on a site-related figure.

Screening Criteria

The criteria used to screen contaminant levels in surface and subsurface soils, surface water, and sediments are not regulatory enforceable standards; rather, they serve as a guideline for determining whether a chemical may have a deleterious effect on potential receptor populations. Federal and Pennsylvania criteria were used in this document; the following paragraphs describe each criteria.

Risk-Based Concentrations (RBCS) And Soil Screening Levels

RBCs are non-enforceable standards derived from standard EPA equations used for EPA Region III risk assessments. The SSLs are non-enforceable standards set by EPA for use in risk assessments in all EPA regions. The RBCs and SSLs used in this report are based on direct ingestion of soil. Additionally, the criteria used in the post-removal screening are based on an industrial scenario and are derived based on a 1E-06 carcinogenic risk or hazard quotation (HQ) of 1.0 (for noncarcinogenic) risk. For the risk-ratio/toxicological evaluation presented in Section 6.0, residential RBCs were used in the COPC selection process for the hypothetical future residential child scenario soil RPCs were also compared to a soil-to groundwater pathway dilution and attenuation factors (DAF). A DAF of 20 was used to account for natural processes that reduce contaminant concentrations in the subsurface. The purpose of this comparison was to identify and screen those hazardous substance concentrations in soil that might have the potential to contaminate groundwater.

Medium-Specific Concentrations (MSCs)

MSCs are non-enforceable standards derived from standard EPA equations used for risk assessments in Pennsylvania. The MSCs used in this risk assessment are based on direct ingestion of soil. Additionally, these standards are based on a residential scenario and are derived based on a 1E-05 carcinogenic risk or an HQ of 1.0 (for noncarcinogenic effects).

Values of the available TBCs for chemicals positively detected in Area A soils are presented in Table 2-7. This table presents values for chemicals having only carcinogenic or noncarcinogenic effects, and for chemicals having both carcinogenic and noncarcinogenic effects.

Ambient Water Quality Criteria (AWQCs)

AWQCs were developed under the Clean Water Act and are non-enforceable federal regulatory guidelines; they are of primary utility in assessing the potential for toxic effects in aquatic organisms. Surface water concentrations were compared to AWQCs to evaluate impacts to aquatic receptors.

Effects Range-Low (ERLs)

NOAA ER-L sediment screening criteria and EPA Region III Biological Technical Assistance Group (BTAG) screening levels for sediment were used to evaluate sediment quality. The ER-Ls for flora/fauna were used.

TABLE 2-7 (PAGE 1 OF 2)
SOIL CRITERIA FOR CHEMICALS DETECTED IN AREA A SOIL
NAWC WARMINSTER, PENNSYLVANIA

SUBSTANCE	PADER MSC INDUSTRIAL SOIL	PADER MSC NON RES. SOIL	EPA RBC INDUSTRIAL SOIL	EPA RBC RESIDENTIAL SOIL	EPA DAF 20 SOIL TO GROUNDWATER
PESTICIDES/PCBs (ug/kg)					
4,4'-DDD	7.50E+04	3.30E+05	2.40E+04	3.00E+03	1.60E+04
4,4'-DDE	5.30E+04	2.30E+05	1.70E+04	2.00E+03	5.40E+04
4,4'-DDT	5.30E+04	2.30E+05	1.70E+04	2.00E+03	3.20E+04
ALDRIN	1.10E+03	4.70E+03	3.40E+02	4.00E+01	5.00E+01
ALPHA-CHLORDANE	1.30E+04	6.10E+04	1.60E+04	5.00E+02	1.00E+04
AROCLOR-1242	3.60E+04	1.60E+05	2.90E+03	1.00E+03	NL
AROCLOR-1248	9.90E+03	4.40E+04	2.90E+03	1.00E+03	NL
AROCLOR-1254	4.40E+03	4.40E+04	2.90E+03	1.00E+03	NL
AROCLOR-1260	3.00E+04	1.30E+05	8.30E+01	1.00E+03	NL
DELTA-BHC	NL	NL	NL	NL	NL
DIELDRIN	1.10E+03	5.00E+03	3.60E+02	4.00E+01	4.00E+00
ENDOSULFAN I	1.30E+06	1.70E+07	1.20E+07	4.70E+05	1.80E+04
ENDOSULFAN II	1.30E+06	1.70E+07	1.20E+07	4.70E+05	1.80E+04
ENDRIN	6.60E+04	8.40E+05	6.10E+05	2.30E+04	1.00E+03
ENDRIN ALDEHYDE	6.60E+04	8.40E+05	6.10E+05	2.30E+04	NL
ENDRIN KETONE	6.60E+04	8.40E+05	6.10E+05	2.30E+04	NL
GAMMA-BHC	1.60E+04	7.20E+04	4.40E+03	4.90E+02	9.00E+00
GAMMA-CHLORDANE	1.30E+04	6.10E+04	1.60E+04	1.80E+03	1.00E+04
HEPTACHLOR	4.00E+02	1.80E+04	1.30E+03	1.00E+02	2.30E+04
HEPTACHLOR EPOXIDE	2.00E+02	8.70E+03	6.30E+02	7.00E+01	7.00E+02
METHOXYCHLOR	1.10E+06	1.40E+07	1.00E+07	3.90E+05	1.60E+05
SEMIVOLATILES (ug/kg)					
1,4-DICHLOROBENZENE	7.50E+05	3.30E+06	2.00E+07	2.70E+04	2.00E+03
2-METHYLNAPHTHALENE	8.80E+06	1.00E+07	NL	NL	NL
3,3'-DICHLOROBENZIDINE	4.00E+04	1.80E+05	1.30E+04	1.00E+03	7.00E+00
4-METHYL-2-PENTANONE	NL	NL	6.30E+06	NL	NL
4-METHYLPHENOL	NL	NL	1.00E+07	NL	NL
ACENAPHTHENE	1.30E+07	1.70E+08	1.20E+08	4.70E+06	5.70E+05
ACENAPHTHYLENE	1.30E+07	1.70E+08	NL	NL	NL
ANTHRACENE	6.60E+07	1.90E+08	6.10E+08	2.30E+07	1.20E+07
BENZ(A)ANTHRACENE	2.50E+04	1.10E+05	7.80E+03	9.00E+02	2.00E+03
BENZO(A)PYRENE	2.50E+03	1.10E+04	7.80E+02	9.00E+01	8.00E+03
BENZO(B)FLUORANTHENE	2.50E+04	1.10E+05	7.80E+03	9.00E+02	5.00E+03
BENZO(G,H,I)PERYLENE	1.30E+07	1.70E+08	NL	NL	NL
BENZO(K)FLUORANTHENE	2.50E+05	1.10E+06	7.80E+05	9.00E+03	5.00E+03
BIS(2-ETHYLHEXYL)PHTHALATE	1.30E+06	5.70E+06	4.10E+05	4.60E+04	3.60E+06
BUTYL BENZYL PHTHALATE	1.00E+07	1.00E+07	4.10E+08	1.60E+07	9.30E+05
CARBAZOLE	NL	NL	2.90E+05	NL	NL
CHRYSENE	2.50E+06	1.10E+07	7.80E+05	8.80E+04	1.60E+05
DI-N-BUTYL PHTHALATE	1.00E+07	1.00E+07	NL	7.80E+06	2.30E+06
DI-N-OCTYL PHTHALATE	NL	NL	4.10E+07	1.60E+06	1.00E+07
DIBENZ(A,H)ANTHRACENE	2.50E+03	1.10E+04	7.80E+02	9.00E+01	2.00E+03
DIBENZOFURAN	NL	NL	8.20E+06	3.10E+05	NL
DIETHYLPHTHALATE	1.00E+07	1.00E+07	1.60E+09	6.30E+07	4.70E+05
FLUORANTHENE	8.80E+06	1.10E+08	8.20E+07	3.10E+06	4.30E+06
FLUORENE	8.80E+06	1.10E+08	8.20E+07	3.10E+06	5.60E+05
INDENO(1,2,3-CD)PYRENE	2.50E+04	1.10E+05	7.80E+03	9.00E+02	1.40E+04
NAPHTHALENE	8.80E+06	1.10E+08	4.10E+07	3.10E+06	8.40E+04
PENTACHLOROPHENOL	1.50E+05	6.60E+05	4.80E+04	3.00E+03	3.00E+01
PHENANTHRENE	6.60E+07	1.90E+08	NL	NL	NL
PHENOL	1.30E+08	1.90E+08	1.20E+09	4.70E+07	1.00E+05
PYRENE	6.60E+06	8.40E+07	6.10E+07	2.30E+06	4.20E+06

NL = NOT LISTED

References:

PADEP, 1996. Statewide Health Standard Tables; Subchapter C Section 250.312 of the PA Land Recycling Program Regulations.

EPA, 2000. EPA Region III Risk-Based Concentration (RBC) Table. Philadelphia, Pennsylvania. April 13.

EPA, 1996e. Soil Screening Guidance (Appendix A). EPA/540/R-95-128. Washington, DC. May.

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TABLE 2-7 (PAGE 2 OF 2)
SOIL CRITERIA FOR CHEMICALS DETECTED IN AREA A SOIL
NAWC WARMINSTER, PENNSYLVANIA

SUBSTANCE	PADER MSC RESIDENTIAL SOIL	PADER MSC NON RES. SOIL	EPA RBC INDUSTRIAL SOIL	EPA RBC RESIDENTIAL SOIL	EPA DAF 20 SOIL TO GROUNDWATER
VOLATILES (ug/kg)					
1,1,2,2-TETRACHLOROETHANE	5.50E+03	2.80E+04	2.90E+02	3.00E+03	3.00E+00
1,1-DICHLOROETHANE	2.00E+05	1.00E+06	2.00E+08	7.80E+06	2.30E+04
1,2-DICHLOROETHENE (TOTAL)	6.70E+05	1.90E+06	1.80E+07	7.80E+05	4.00E+02
TRANS-1,3-DICHLOROPROPENE	NL	NL	3.20E+04	4.00E+03	4.00E+00
2-BUTANONE	NL	NL	4.70E+07	NL	NL
ACETONE	1.00E+07	1.00E+07	2.00E+08	7.80E+06	1.60E+04
BENZENE	3.80E+04	2.00E+05	1.00E+05	1.20E+04	3.00E+01
BROMOMETHANE	9.50E+04	2.70E+05	2.90E+06	NL	NL
CARBON DISULFIDE	1.00E+07	1.00E+07	2.00E+08	7.80E+06	3.20E+04
CHLOROBENZENE	4.40E+06	1.00E+07	4.10E+07	1.60E+06	1.00E+03
CHLOROETHANE	1.00E+07	1.00E+07	2.00E+06	2.20E+05	NL
CHLOROMETHANE	NL	NL	4.40E+06	NL	NL
CHLOROFORM	1.40E+04	7.20E+04	9.40E+05	1.00E+05	6.00E+02
ETHYLBENZENE	1.00E+07	1.00E+07	2.00E+08	7.80E+06	1.30E+04
METHYLENE CHLORIDE	1.80E+05	9.20E+05	7.60E+05	8.50E+04	2.00E+01
TETRACHLOROETHENE	3.40E+05	1.50E+06	1.10E+05	1.20E+04	6.00E+01
TOLUENE	7.60E+06	1.00E+07	4.10E+08	1.60E+07	1.20E+04
TRICHLOROETHENE	1.90E+05	9.70E+05	5.20E+05	5.80E+04	6.00E+01
XYLENES (TOTAL)	1.00E+07	1.00E+07	4.10E+09	1.60E+08	1.90E+05
DIOXINS/FURANS (ug/kg)					
OCDD	NL	NL	4.10E+00	NL	NL
OCDF	NL	NL	4.10E+00	NL	NL
INORGANICS (mg/kg)					
ALUMINUM	1.90E+05	1.90E+05	2.00E+06	7.80E+04	NL
ANTIMONY	8.80E+01	1.10E+03	8.20E+02	3.10E+01	5.00E+00
ARSENIC	1.20E+01	5.30E+01	3.80E+00	4.30E-01	2.90E+01
BARIUM	1.50E+04	1.90E+05	1.40E+05	5.50E+03	1.60E+03
BERYLLIUM	4.20E+00	1.80E+01	4.10E+03	1.00E-01	6.30E+01
CADMIUM	1.10E+02	1.40E+02	1.00E+03	7.80E+01	8.00E+00
CALCIUM	NL	NL	NL	NL	NL
CHROMIUM (+3)	1.90E+05	1.90E+05	3.10E+06	7.80E+04	NL
COBALT	1.30E+04	1.70E+05	1.20E+05	NL	NL
COPPER	8.10E+03	1.90E+05	8.20E+04	NL	NL
CYANIDE	4.40E+03	5.60E+04	4.10E+04	1.60E+03	4.00E+01
HEXAVALENT CHROMIUM	1.10E+03	1.40E+04	6.10E+03	3.90E+02	3.80E+01
IRON	6.60E+04	1.90E+05	6.10E+05	NL	NL
LEAD	5.00E+02	1.00E+03	NL	4.00E+02	NL
MAGNESIUM	NL	NL	NL	NL	NL
MANGANESE	1.00E+04	1.30E+05	4.10E+04	NL	NL
MERCURY	1.90E+01	2.40E+02	6.10E+02	NL	NL
NICKEL	4.40E+03	5.60E+04	4.10E+04	1.60E+03	1.30E+02
POTASSIUM	NL	NL	NL	NL	NL
SELENIUM	1.10E+03	1.40E+04	1.00E+04	3.90E+02	5.00E+00
SILVER	1.10E+03	1.40E+04	1.00E+04	3.90E+02	3.40E+01
SODIUM	NL	NL	NL	NL	NL
THALLIUM	1.80E+01	2.20E+02	1.40E+02	NL	7.00E-01
VANADIUM	1.30E+01	1.60E+02	1.40E+04	5.50E+02	6.00E+03
ZINC	6.60E+04	1.90E+05	6.10E+05	2.30E+04	1.20E+04

NL = NOT LISTED

References:

PADEP, 1996. Statewide Health Standard Tables; Subchapter C Section 250.312 of the PA Land Recycling Program Regulations.
EPA, 2000. EPA Region III Risk-Based Concentration (RBC) Table. Philadelphia, Pennsylvania. April 13.
EPA, 1996e. Soil Screening Guidance (Appendix A). EPA/540/R-95-128. Washington, DC. May.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Several environmental studies have been completed at NAWC Warminster. A number of these, including studies by JRB Associates (1981 and 1983), Sloto and Davis (1983), Satterthwaite (1984), and Earth Technology Corporation (1985), have provided information on local surface features, soils, meteorology, surface water hydrology, demography and land use, and hydrogeology. The following description of the physical characteristics of NAWC Warminster has been prepared on the basis of published information, reports of previous site studies, and information obtained and interpreted during the course of the RI. Section 3.0 provides a brief, general overview of the overall physical characteristics of the facility and specific physical characteristics for Area A, including Sites 1, 2, 3, and the Impoundment Area.

3.1 METEOROLOGY

The climate of the area is humid continental and is modified by the Atlantic Ocean. Temperatures average 76°F (24.4°C) in July and 32°F (0°C) in January. The average daily temperature for the NAWC location is 53.3°F (11.8°C). Precipitation averages 42.5 inches per year (106.25 cm per year), and snowfall averages 22 inches per year (55 cm per year). The distribution of precipitation is fairly even throughout the year. The relative humidity for the site averages 70 percent. The mean wind speed for this area is 9.6 mph, with a prevailing direction west-southwest (U.S. Navy, 1990).

3.2 SURFACE WATER HYDROLOGY AND TOPOGRAPHY

NAWC Warminster lies in a populated suburban area surrounded by private homes and various commercial/industrial activities. The complex covers approximately 734 acres located in the township of Warminster, Pennsylvania, Bucks County. On-site areas include various buildings and other complexes connected by paved roadways, the runway and ramp area, mowed fields, and a small wooded area. Off-site areas consist of wooded, park, and residential areas and commercial/industrial facilities.

The facility is situated on an upland area divided between two local drainage basins, the Little Neshaminy Creek Basin on the north and the Southampton Creek basin on the south. The northern 65 percent of the facility (including Areas A and C) drains toward the north through several swales and storm sewers into small unnamed tributaries of Little Neshaminy Creek. The southern 35 percent of the facility (including Area B) drains toward the south to the headwaters of Southampton Creek, a tributary of Pennypack Creek. Both local drainage basins lie within the regional drainage basin of the Delaware River. Various studies conducted on the site have revealed that no areas within NAWC Warminster are included in the 100-year or 500-year floodplain.

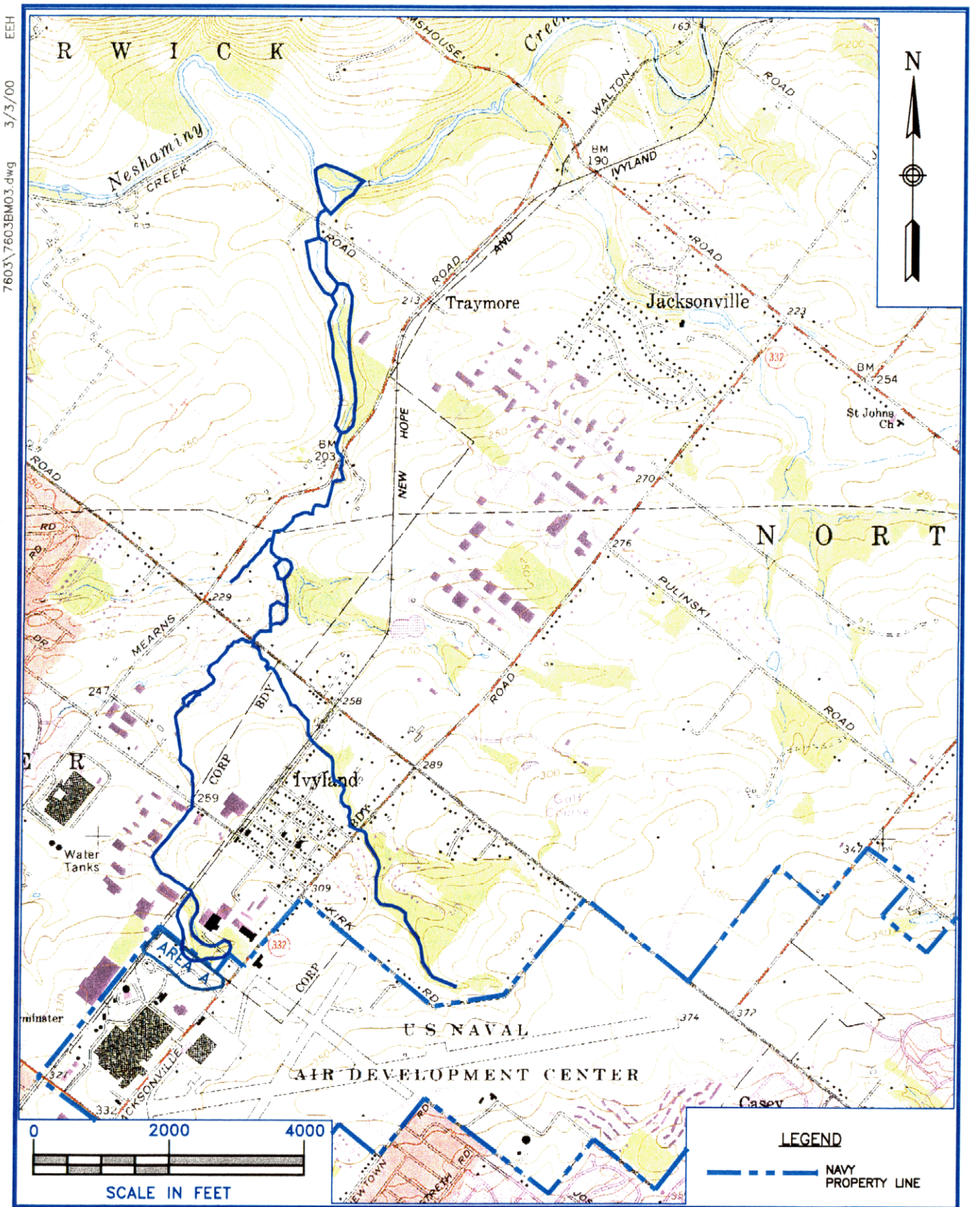
Much of the natural drainage pattern has been altered by development, and drainage within developed areas of the NAWC Warminster property is controlled primarily through constructed drainage systems. A significant portion of precipitation runoff is directed by surface grading and paving to constructed ditches, culverts, and storm sewers. Several of the tributaries of Little Neshaminy and Southampton Creeks originate at, or near, the outfall points of these culverts adjacent to the facility boundary. Springs and seeps contributing to surface water flow have been reported or observed near the facility boundary in the vicinity of all sites except Site 8 (JRB Associates, 1981 and SMC Martin, 1991). An underground tile drainage system was used to drain the eastern portion of the facility when it was farmed in the 1940s (JRB Associates, 1981). The present condition of the tile drains and their influence on surface or near-surface drainage are unknown.

The location of NAWC Warminster represents a relative topographic high, based on the USGS quadrangle for the vicinity (Hatboro, Pennsylvania quadrangle, 1966). The crest of a local hilltop trends from west to east within the facility and is roughly coincident with the location of the main runway. Surface topography within the facility slopes away from the main runway to the north, west, and south, precluding surface water flow onto the facility from surrounding properties. Slopes range from nearly level to eight percent and average from three to five percent. Surface elevations range from a high of approximately 380 feet mean sea level (MSL) near the eastern end of the main runway to a low of approximately 300 feet where a small stream exits the northwestern part of the facility.

3.2.1 Area A Hydrology And Topography

Area A is located on the northern boundary of NAWC Warminster, east of Jacksonville Road (see Figure 1-3). The sites are located on a generally flat-lying area. The unnamed tributary of Little Neshaminy Creek is located north of Area A, and the wastewater treatment facility, jet fuel storage area, and parking lots are immediately to the south.

An unnamed tributary of Little Neshaminy Creek is located north of Area A (Figure 3-1). This stream originates from a stormwater culvert under Jacksonville Road and flows from the southeast to the northwest before turning north, away from NAWC Warminster. Between the base boundary and Bristol Road, the stream flows north under Means Road through pastures and small woodlots to the stream's junction with Little Neshaminy Creek approximately 0.5 mile northwest of Traymore Borough on Creek Road. The stream near the base boundary is 2 feet wide and 2 to 3 inches deep with sand and gravel bottoms. As the stream approaches Little Neshaminy Creek, it widens to 10 feet and is over 6 inches deep. Several holes greater than 12 inches in depth were observed. The downstream portions of the stream are characterized by a rocky bottom with 2- to 3-foot cut banks. Flow rates were estimated in several of the narrow, faster-



DRAWN BY	DATE	Tetra Tech NUS, Inc.	STREAMS LOCATED NORTH OF AREA A	CONTRACT NO. 7603
LDL/EEH	3/2/00		FORMER NAWC WARMINSTER	OWNER NO. 0601
CHECKED BY	DATE		WARMINSTER, PENNSYLVANIA	APPROVED BY / DATE
REVISED BY	DATE			DRAWING NO. FIGURE 3-1 / REV.
SCALE 1 IN.= 2000 FT.				

SOURCE: (7.5 MINUTE SERIES) U.S.G.S. HATBORO, PA QUADRANGLE

EEH 3/3/00 7603\7603BM03.dwg

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flowing areas at approximately 3 gallons per minute (gpm). During base-flow conditions (i.e., when groundwater discharge into the stream contributes most of, it not all, the stream's flow), large sections of the stream appear stagnant.

Surface water drainage from portions of the airfield and hangar area discharges from a culvert located near where the stream originates. Surface water runoff from Area A and adjacent areas also enters the stream as overland flow. A culvert located near the point where the stream turns to the north and exits the property (OF1 as shown on Figure 2-3) was observed to be discharging water to the stream during the Phase II investigation. Groundwater flow patterns indicate that overburden, and possibly shallow bedrock groundwaters, also discharge to the stream.

Historical aerial photographs (circa 1940s and 1950s) indicate that a stream once drained the area in the vicinity of the main building complex at the base as well as portions of Area A. This stream originated west of Building 2 and flowed northwestward until it exited the base property. The stream and a ravine formed by its erosion action were filled when the stream was replaced by a storm sewer. The current outfall (OF1) within Area A and along the base boundary may represent the original discharge point of this stream to the unnamed tributary of Little Neshaminy Creek. This outfall lies downgradient of a disturbed area (DG3) and former dump (D1) (as identified by EPIC). The second outfall (OF2) within Area A probably represents stormwater drainage from the parking lot south of the guardhouse.

The stream adjacent to Area A is a small urban headwater reach, but it appears to be perennial. The portion of the stream within the NAWC Warminster property is channelized with a very high (10 to 12 feet) and steeply sloped (4:1 to 5:1) southern bank that leads up to a paved driveway and parking area near Site 2 and to a gravel parking area in the vicinity of Site 3. The stream channel averages approximately 4 feet in width and 5 inches in depth. It contains some pool areas of 1 to 2 feet or more in depth. The streambed is very rocky and gravelly, with little fine sediment. Construction debris such as concrete and some steel or aluminum metal debris were observed in the stream during the RI activities.

No springs were seen on or adjacent to Area A. Isolated and/or displaced fragments of the underlying bedrock were observed in the stream embankment north of the sites.

Several orange-colored seeps were observed along the creek bank north of Sites 2 and 3 during the Phase III RI. The seeps were found at several points along the creek, suggesting that there may be more than one entrance point of the seep into the creek. Preliminary analysis of the seep with the portable GC during Phase I indicated that no volatile compounds were present. It is not known if the seep material is spring fed.

3.3 SOILS

According to the Soil Survey of Bucks and Philadelphia Counties, Pennsylvania (USDA, 1975), the sites at NAWC Warminster are underlain by five major soil types. These are Urban land and soils of the Duncannon, Lawrenceville, Chalfont, and Doylestown Series (see Table 3-1).

Urban land occurs in highly developed areas where urban structures and works cover so much of the land type that identification of the soils is not practical. Most areas have been graded, and the original soil material has been disturbed, filled over, or otherwise altered prior to construction. As a consequence of these activities, the soil and foundation materials may be highly variable. The Urban land type within the facility is classified as Urban land Lansdale complex, zero to eight percent slopes. It consists of approximately 60 percent urban land, 35 percent Lansdale soils, and five percent other soils. Also included are some areas of various types of fill material. This complex has good drainage and is nearly level to gently sloping.

Duncannon soils are deep, well drained, and nearly level to gently sloping. They occur on the upper elevations of low-relief upland areas and formed in silty wind-deposited sediment overlying shale and sandstone bedrock. The soils consist primarily of brown, yellowish-brown, dark brown, and dark reddish-brown silt loam and shaly silt loam. These soils have moderate permeability ranging from 4.4×10^{-4} cm/sec to 1.4×10^{-3} cm/sec. The depth to bedrock and the seasonal high water table are each typically greater than 4 feet below the surface.

Lawrenceville soils are deep, moderately well drained, and nearly level to gently sloping. They occur on the middle and lower elevations of low relief upland areas and formed in silty wind blown deposits underlain mainly by material weathered from shale and sandstone. The soils consist primarily of dark brown, yellowish-brown, and brown silt loam with some sandy loam in the substratum. These soils have moderately slow permeability ranging from 1.4×10^{-4} cm/sec to 4.4×10^{-4} cm/sec. The depth to bedrock is typically from 4 to 8 feet below the surface, and the seasonal high water table may be within 18 to 36 inches of the surface in wet seasons.

Chalfont soils are deep, somewhat poorly drained, and nearly level to gently sloping. They occur in concave positions on low-relief uplands and formed in the silty wind-blown mantle overlying loamy material weathered from red and brown shale and sandstone. The soils consist primarily of brown, dark yellowish-brown and grayish-brown, silt loam, silty clay loam, and shaly silt loam that may be compact, firm, and brittle within the subsoil. These soils have slow permeability of less than 1.4×10^{-4}cm/sec. The depth to bedrock is typically from 4 to 8 feet below the surface, and a high water table is within 6 to 18 inches of the surface in wet seasons.

TABLE 3-1
NAMC WARMINSTER SOILS

Site	Mapped Soil Series
1, 2, and 3	Urban land—Landsdale complex, 0-8% slopes
4	Chalfont silt loam, 3-8% slopes Duncannon silt loam, 3-8% slopes
5, 6, and 7	Lawnrenceville silt loam, 0-3% slopes Lawrenceville silt loam, 3-8% slopes Duncannon silt loam, 3-8% slopes Doylestown silt loam, 0-3% slopes
8	Urban land – Lansdale complex, 0-8% slopes

Reference: Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture, Soil Conservation Service, 1975.

Doylestown soils are deep, poorly drained, and nearly level to gently sloping. They occur at the bases of slopes and in depressions and formed in silty wind-blown deposits overlying loamy material weathered from shale and sandstone. The soils consist primarily of grayish-brown and dark grayish-brown to brown and dark brown silt loam and silty clay loam that is firm, dense, and brittle at places within the subsoil. These soils have slow permeability of less than 1.4×10^{-4} cm/sec. The depth to bedrock is typically 4 to 7 feet below the surface, and a seasonal high water table is at or near the surface in wet seasons.

Soil thicknesses in the vicinity of Area A ranged from 6.5 to 16 feet in depth. The soil appeared to be thinnest (6.5 to 8 feet) north of the former wastewater impoundments adjacent to Site 1. Soil types observed at Area A were mostly orange-red, red, and brown silt with less common thin beds of red and tan, fine- to medium-grained arkosic sand.

The United States Soil Conservation Service (SCS) has mapped the soil at Area A as "Urban land soils". During Phase I, waste material was discovered, including cinders and wood, glass and metal fragments, indicating that these soils have been reworked.

3.4 REGIONAL GEOLOGY

NAWC Warminster is located in the Piedmont Physiographic Province and Triassic Lowlands Section of southeastern Pennsylvania. The province is extensive and gently undulating and generally slopes to the southeast. The land forms have been modified by erosion to form moderate slopes and gently rounded hills with a dendritic drainage pattern.

The bedrock underlying NAWC Warminster belongs to the late Triassic age Stockton Formation. The Stockton Formation is unconformably underlain by basement rocks of Ordovician to PreCambrian age that crop out approximately 2 miles south of the facility. The Stockton Formation is conformably overlain by the shale- and argillite-rich Lockatong Formation, also of late Triassic age, which crops out approximately 2.5 miles north of the facility.

Within the general area surrounding NAWC Warminster, the beds of the Stockton are reported to strike to the northeast and dip from 7 to 16 degrees to the northwest, with an average regional dip of about 12 degrees (Rima, et al., 1962). Based on its outcrop width and this regional dip, the Stockton Formation is estimated to be approximately 2,200 feet thick beneath NAWC Warminster.

The Stockton Formation is extensively faulted by small displacement normal faults and is cut by well-developed joint systems. The joint sets occur in a discernible and predictable pattern. The most frequently occurring joint sets trend perpendicular and parallel to the strike of the bedding. Another commonly occurring joint set trends to the northwest at an angle of about 50 degrees from strike (Rima, et al., 1962).

The Stockton Formation is composed of fine- to coarse-grained arkosic sandstone and conglomerate interbedded with shale and siltstone. These rocks are interpreted to have been deposited by coalescing alluvial fans that deposited sediment eroded from highlands to the south (Sloto and Davis, 1983). Throughout the Stockton Formation, units of varying lithology are irregularly interbedded, with coarse-grained units commonly overlying fine-grained units. Beds commonly pinch out or form gradational contacts with overlying or underlying beds over lateral distances greater than several hundred feet (Rima, et al., 1962).

The Stockton Formation is divided into the lower arkose, middle arkose, and upper shale members. Detailed geologic mapping of these three members is not available within Bucks County. However, projections from geologic maps for the area 1 mile west of the NAWC Warminster indicate that the facility is underlain by the middle arkose member of the Stockton Formation (Rima, et al., 1962).

The middle arkose member of the Stockton Formation consists of beds of fine- and medium-grained arkosic sandstone with interbedded red shale, siltstone, and very fine-grained red sandstone and a few beds of coarse-grained arkose. Beds of shale and siltstone are more common in the upper portion of the member, and coarser-grained units are more common in the lower portion. Many of the beds in the middle arkose member are well sorted and weakly cemented, which creates a relatively high porosity compared to the lower and upper members (Rima, et al., 1962). The thickness of the middle arkose member beneath NAWC Warminster is unknown but is estimated to range from approximately 500 feet thick near the southeastern boundary of the facility to about 1,500 to 2,000 feet thick near the northwestern boundary.

The lower arkose member of the Stockton Formation underlies the middle arkose member and is projected to crop out approximately 2,000 feet or more southeast of the base. The lower arkose member is dominated by coarse-grained arkosic sandstone and conglomerate. Beds of medium-grained arkosic sandstone are common, though less abundant than the coarser-grained units. The lower arkose member is estimated to be approximately 1,700 to 1,800 feet thick in the vicinity of NAWC Warminster (Rima, et al., 1962).

The upper shale member of the Stockton Formation is not present in the vicinity of the base, but it overlies the middle arkose member several miles northwest of the facility. The upper shale member consists of shale, siltstone, and fine-grained arkosic sandstone. The sandstone is most common in the lower portion of this member.

3.4.1 Area A Geology

The following discussion is an overview of the Area A geology. A more detailed discussion of site geology and hydrogeology is presented in the Focused RI Report for Groundwater, dated 1995 (HNUS, 1995e).

The geology within Area A consists of a thin veneer of residual soils overlying the sedimentary bedrock of the Stockton Formation. The soils primarily consist of silt and clay, with minor amounts of sand and rock fragments. Typically, the soils grade into weathered bedrock at depths of about 8 to 10 feet bgs and to competent bedrock at a depth of about 15 feet. The transition from soils to competent bedrock occurs gradually and varies somewhat in depth throughout the area. The bedrock surface generally slopes to the north and northwest and is similar to the ground surface slope.

The bedrock within Area A consists of alternating sequences of fine- and coarse-grained, gently dipping rock units. Lithologic units typically vary in thickness from less than 1 foot to about 40 feet, with some coarser-grained sequences locally reaching thicknesses of about 80 feet. The fine-grained units consist primarily of red-brown siltstones and shales. The coarse-grained units typically consist of fine- to coarse-grained arkosic sandstones that range in color from red-brown to gray and green-gray. Transitions from one lithology to another range from well-defined, gradational sequences to abrupt lithologic changes.

Individual rock units vary both in thickness and in areal extent, with some lithologies extending for significant distances across Area A and others pinching out within relatively short distances. Thicker beds typically extend laterally for greater distances than thinner beds. Fine-grained beds tend to be more laterally extensive than the coarser-grained rock units, although coalescing sandstone beds may form laterally and vertically extensive packages of coarse-grained sediments.

Transitions from one lithology within Area A, a bedrock strike of north 64 degrees east, and a dip of 7 degrees to the northwest, were measured based on correlations that were made among geophysical logs

from selected well borings. The dip of the rock is generally consistent with the overall topographic slope within Area A. Fractures were encountered at varying depths within the well borings. The fractures occur at lithologic contacts (bedding- plane fractures) and as fractures cutting across sedimentary units. Both the finer- and coarser-grained rock types are fractured to varying degrees.

3.5 REGIONAL HYDROGEOLOGY

The fractured bedrock of the Stockton Formation is the major source of groundwater in the vicinity of NAWC Warminster. The middle arkose member of the Stockton Formation is considered to be the most productive bedrock aquifer in Bucks County.

Within the water-bearing zones in the fine- and medium-grained sandstones of the Stockton Formation, groundwater is transmitted chiefly through fractures, joints, and bedding planes (secondary permeability and porosity). Primary porosity is generally minimal in these rock units. The shale and siltstone beds are commonly too fine grained to transmit large amounts of groundwater through primary porosity, and the fractures are typically not as well developed compared to the coarser-grained units. Consequently, the shale and siltstone beds often act as confining layers to groundwater. The bulk of the groundwater is transmitted through the fractures and, to a lesser extent, the primary porosity of the sandstones.

The Stockton Formation in the vicinity of NAWC Warminster forms a complex, multi-aquifer system. The individual water-bearing zones of the Stockton Formation may belong to either of three different aquifer types which, in descending subsurface order, include

- Overburden (weathered bedrock) aquifer
- Shallow bedrock aquifer
- Deeper bedrock aquifer

The overburden aquifer consists of soil and saprolite (weathered bedrock) derived from the erosion of the truncated edges of the inclined bedrock layers. The overburden aquifer generally extends to an average depth of about 20 feet.

The shallow bedrock aquifer underlies the overburden aquifer and may extend to depths of about 75 to 120 feet bgs. The shallow bedrock aquifer is recharged by vertical percolation from the overburden aquifer and is the primary reservoir for groundwater storage in the Stockton Formation. The shallow bedrock aquifer occurs within the weathered and unweathered shallow bedrock and is generally under water-table or unconfined conditions. The shallow bedrock aquifer may consist of numerous discrete water-bearing zones. Horizontal groundwater migration in response to regional gradients (controlled by topography or long-term well pumping) is significant in the shallow bedrock aquifer.

The deeper bedrock aquifer underlies the shallow bedrock aquifer and typically occurs at depths greater than about 75 to 120 feet bgs. Water within the deeper bedrock aquifer occurs under semi-confined or confined conditions. Leakage from one water-bearing unit to another occurs when there is a difference in the hydraulic head between the units. Groundwater flow is from the unit with a higher hydraulic head to the unit with a lower hydraulic head and can be either upward or downward. Pumping effects may either amplify or reduce the leakage rate, depending on whether the pumping increases or decreases the difference in hydraulic head.

Groundwater flow directions within the Stockton Formation are variable and are controlled by topography, bedrock structure, and the locations of groundwater discharge points such as streams and wells.

3.5.1 Area A Hydrogeology

Groundwater within Area A is primarily encountered within the bedrock of the Stockton Formation. The overlying soils contain minor amounts of water in some areas, primarily near the base boundary along the northern edge of Area A. Due to the limited extent of the saturated soils and the clayey nature and resulting low permeability of the soils, this groundwater migration pathway is of minor significance in comparison to the bedrock groundwater flow system.

The primary migration pathway for the groundwater within the bedrock is within the extensive network of interconnected fractures. Some minor primary or intergranular porosity also contributes to the system, especially in the sandstone units. In general, the sandstone units function as the primary water-transmitting units, and the siltstones and shales act as semiconfining layers to groundwater flow. Although all rock types are fractured to varying degrees, the fractures within the sandstones tend to have higher yields.

The groundwater flow direction in the shallow bedrock (to a depth of approximately 90 feet) and intermediate bedrock (to a depth of approximately 150 feet) is to the north-northwest, with average horizontal gradients of 0.02 and 0.025, respectively. The flow direction and gradient are similar to the dip of the bedrock and the slope of the ground surface and are in the direction of several unnamed tributaries to Little Neshaminy Creek. The groundwater flow within the deep bedrock (to a depth of approximately 300 feet) is to the north-northeast.

Vertical groundwater flow gradients are generally upward, from deeper flow zones to shallow flow zones. The overall pattern of vertical head differentials indicates that groundwater in the bedrock exists under semiconfined conditions. The laterally persistent mudstone units are believed to function as the semiconfining layers.

More detailed information on the geology and hydrogeology of Area A is presented in the Phase II RI Report for OU-1 (HNUS, 1993a) and the Draft Focused RI Report for Groundwater (HNUS, 1995e).

3.6 GROUNDWATER USE

NAWC Warminster and nearby residents and businesses rely primarily on groundwater for their water supply. The majority of these people are served by municipal water authorities, and the remainder utilize private domestic or commercial wells.

Residential wells occur throughout a 1-mile radius from the base. The largest clusters of wells are generally located south of the base. All residential wells around the base have been sampled by the Navy at least once, and most have been sampled multiple times as part of Navy's groundwater monitoring program.

A survey was performed to identify major pumping wells within an approximate 1-mile radius around NAWC Warminster (B&R Environmental, 1996a). The purpose of this survey was to determine where the major groundwater withdrawal centers around the base are located. These withdrawal centers may influence local groundwater flow patterns. A total of 37 public supply and industrial wells (including the 11 on-base wells) were identified within approximately 1 mile from the base. A total of 29 of these wells are currently active. All available data, including construction details and current and historic usage patterns, are summarized in the referenced report.

3.6.1 Area A Groundwater Use

Residents near Area A rely entirely on groundwater sources for their water supply. The majority of these people are served by the Warminster Township Municipal Authority (WTMA), and the remainder use private domestic wells. The nearest municipal supply well, WTMA Well No. 26, is less than 2,000 feet from the base boundary. The closest active well serves a commercial business, which is 800 feet northeast of Site 3.

Well No. 26 is a 10-inch-diameter well and is 250 feet deep. It is cased to a depth of 70 feet bgs and the average daily withdrawal rate is about 340,000 gallons, based on 1994 data.

The closest former well near Area A was a production well about 400 feet north of Site 2. This well was decommissioned for production water in 1995 when a public water connection was made.

3.7 ECOLOGY

Openland, woodland, and wetland habitats are all found within or near the facility. These include mowed fields and lawns, nonforested overgrown land, wooded areas, forested wetlands, scrub/shrub wetlands, and streams and their adjacent riparian areas. There are no known critical habitats of endangered species located within 1 mile of the facility (NUS, 1985).

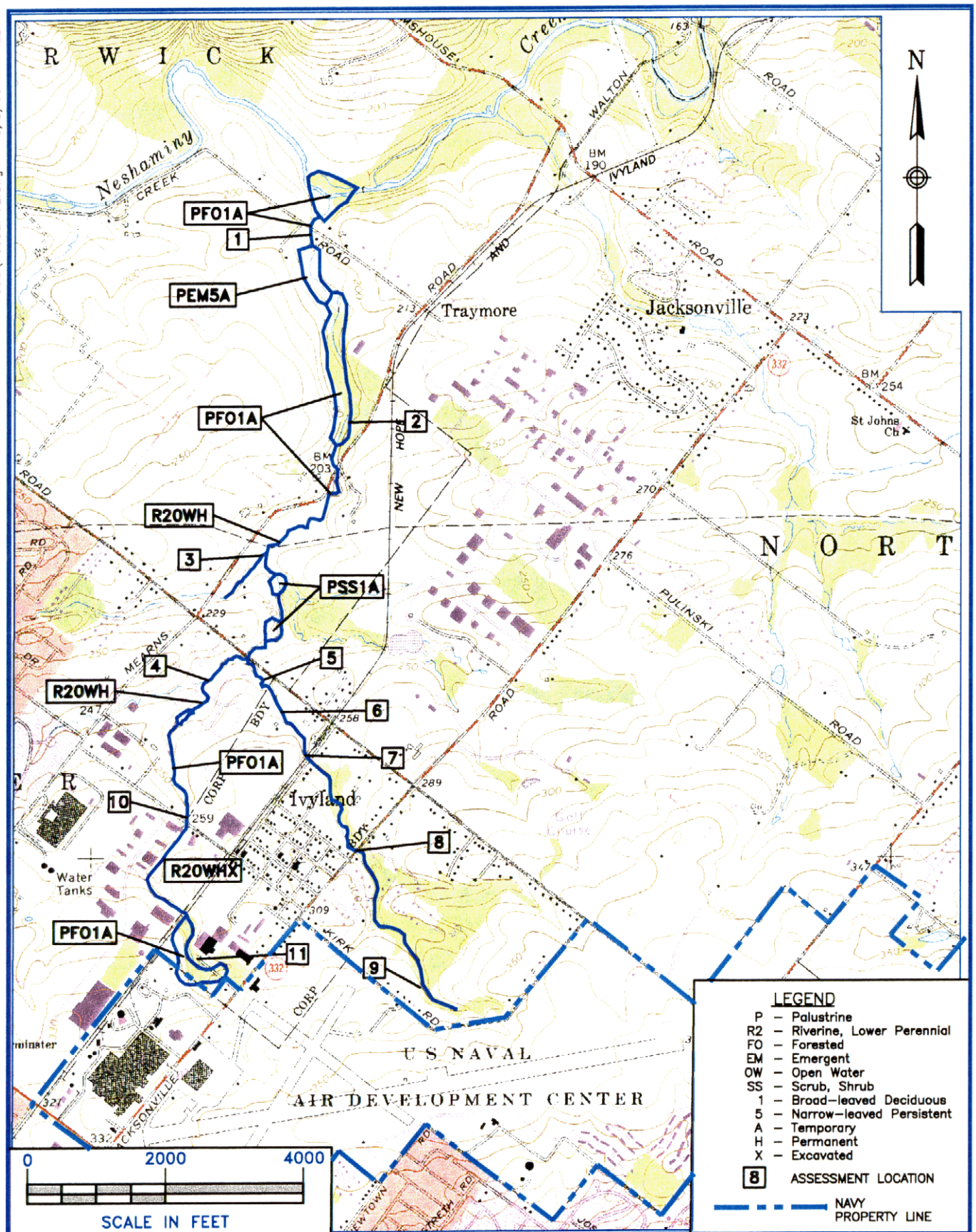
Mourning doves, pheasants, and various songbirds such as sparrows, red-winged black birds, goldfinches, cardinals, blue jays, and robins are present throughout NAWC Warminster. Canada geese and ducks have been observed in the streams south of Area B and north of Area A. Snakes, leopard frogs, and muskrat have also been observed in or near the stream north of this area. Snails, earthworms, amphipods, and larval insects have been observed. Small fish or minnows tentatively identified as creek chubs are present in each of the streams from which surface water and sediment samples were obtained. White-tailed deer, groundhogs, rabbits, and squirrels are common throughout the facility. Raccoon tracks have been observed in several adjacent streams.

3.7.1 Area A Ecology

The south bank of the stream was sparsely vegetated with various wildflowers, vines, and shrubs (i.e., goldenrod, greenbriar, and blackberry). The north bank is more gradually sloped and is vegetated with similar herbaceous plants and shrubs. A small forested wetland dominated by mature red maple and arrowwood is just north of the stream and beyond the fence-line that delineates the limit of the NAWC Warminster property. At the time of the biological characterization, an orange-colored flocculent, presumed to be oxidized iron precipitate, was observed in certain sections of the channelized stream reach. A relatively small amount of epilithic and filamentous algae was covered with the orange material, as were nearby sediments. Substrates in this stream reach were sands and small gravel, and fine sediments (i.e., silts) had accumulated in each of the pools.

Snails and earthworms were commonly found in this part of the stream. Larval insect families (e.g., midges, mayflies) were not collected during the characterization. Small fish, believed to be creek chubs, were seen in the pool near Jacksonville Road but were not seen in the pool at the opposite end of the study area. Leopard frogs were observed along the edge of the stream. Neither turtles nor snakes were found, but they are believed to inhabit the riparian zone of the stream and adjacent wetland. Songbirds (including sparrows, red-winged black birds, and goldfinches) were common in shrubs and trees near the edge of the stream. During subsequent investigations, a nesting female duck was also observed along the edge of the stream. Raccoon tracks were observed on a sand bar in the stream.

Wetlands were assessed along the unnamed tributary of Little Neshaminy Creek that flows north of Area A (HNUS, 1994d). Six locations (Points 1 through 4, 10, and 11) were evaluated (Figure 3-2). Point 11, located between the base boundary and the Wagner & Sons property, is one of the two closest surface waters to the base. It is probably fed by a combination of rainfall (watershed runoff), stormwater runoff from roads, and groundwater. Urban impacts from residential septic tanks, lawn runoff (pesticides and fertilizers), and industrial runoff from parking lots and storage facilities are minimal upstream of this point. No fish kills, stressed vegetation, or other evidence of pollution or contaminated water were observed.



DRAWN BY	DATE			
LDL/EEH	3/2/00	Tetra Tech NUS, Inc.	WETLANDS ALONG THE STREAMS NORTH OF NAWC WARMINSTER	CONTRACT NO. 7603
CHECKED BY	DATE		FORMER NAWC WARMINSTER	OWNER NO. 0601
REVISED BY	DATE		WARMINSTER, PENNSYLVANIA	APPROVED BY / DATE
SCALE 1 IN.= 2000 FT.				DRAWING NO. FIGURE 3-2 / REV.

SOURCE: (7.5 MINUTE SERIES) U.S.G.S. HATBORO, PA QUADRANGLE

EEH 3/2/00 7603\7603BM02.dwg

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At Point 11, the tributary was 2 feet wide and 2 inches deep and characterized by a sandy/mud bottom. The banks were 6 inches high. The National Wetlands Inventory (NWI) map indicated that much of the wooded area east of Jacksonville Road was classified as palustrine, forested, broad-leaved deciduous, temporary (PF01A). Mature silver maple and green ash dominated the canopy. A sparse sub-canopy was dominated by spicebush. The stream became more distinct near the Wagner plant approximately 300 feet from the base boundary where it exited a small spicebush scrub-scrub swamp with a dense herbaceous layer of jewelweed and skunk cabbage.

The Bowmansville silt loam soil was hydric at Point 11 with saturated conditions at the soil surface. The forest associated with the stream provides good excellent habitat for a large variety of wildlife. Birds were observed throughout this area, including wood thrush, tufted titmouse, black-capped chickadee, European starling, common crow, house sparrow, gray catbird, common yellowthroat, American robin, chimney swift, common grackle, turkey vulture, blue jay, and downy woodpecker.

Farther downstream at Point 10, the tributary was a 3-foot-wide, 3-inch deep stream meandering through an 8-foot-wide rocky streambed. The banks were 3 to 4 feet high. Point 10 was located between Jacksonville and Mearns Roads. The NWI map indicated that the streambed and banks were classified PF01A downstream from the road crossing and riverine, lower perennial, open water, permanent excavated (R2OWHx) upstream of the road crossing. The area upstream of the crossing was an excavated storm ditch through an industrial area. Silver maple, green ash, and box elder were located adjacent to the stream downstream of the road, and only grasses and blackberry lined the ditch upstream of the road.

At Point 4, the unnamed tributary was 2 feet wide and 6 inches deep and characterized by a rocky bottom. The banks were 2 feet wide. The NWI map indicated that this area was classified as riverine, lower perennial, open water, permanent (R2OWH). The stream flowed through the backyards of several single-family residences within a subdivision between Mearns and Bristol Roads. Mowed and maintained lawns extended to the top of the bank, which had scattered silver maple and weeping willow. Toys were observed in and adjacent to the stream, indicating that children frequently play and wade in the stream. The only animal observed was an American robin.

Downstream from Point 4 at Point 3, the stream was 10 feet wide and 6 inches deep and had a rocky bottom. The banks were 3 feet high. Point 3 was also downstream from where the tributary draining Area C flows into the tributary draining Area A and where sanitary wastewaters are discharged from the NAWC Warminster wastewater treatment plant. The Bowmansville silt loam floodplain soil at this location was hydric, although it was not indicative of a wetland. The NWI map classified this area as palustrine, emergent, narrow-leaved persistent, seasonal (PEM5C); however, the area had been filled for a new office building and the only wetland habitat was a 4- to 5-foot wide strip of vegetation along the stream that would

be classified as PF01A. The vegetation was primarily silver maple, green ash, and blackberry. No animals were observed.

The farthest downstream points (i.e., 1 and 2) were near Creek Road and Mearns Road, respectively. The stream was 10 feet wide and 6 inches deep and had a rocky bottom. The banks were 3 feet high and the Bowmansville silt loam floodplain soils at these locations were hydric, although at Point 1 the soil was indicative of a wetland. The floodplain ranged from 100 to 200 feet wide and was characterized by red oak, green ash, black cherry, black walnut, American beech, silver maple, and tree of heaven. The dominant understory species were blackberry, Japanese honeysuckle, and lawn grasses. The NWI map classified the stream, stream banks, or the floodplain at these points as PF01A. At Point 2, the wooded wetlands were characterized by ridges and sloughs that differed in elevation by 2 to 3 feet. Evidence of overbank flooding was common throughout these woods.

Several birds and animals were seen in the vicinity of Points 1 and 2. Birds included the gray catbird, purple finch, American robin, black-capped chickadee, ruby-throated hummingbird, orchard oriole, yellow warbler, mourning dove, common grackle, red-winged blackbird, common yellowthroat, and song sparrow. Tracks of animals observed included the white-tailed deer and raccoon. Fish up to 3 inches long were common in the stream. The wooded stream corridor along this segment of the stream was one of the largest woodlands in the surrounding area.

The wetlands assessment in the vicinity of Area A concluded that the stream and wetlands appear to be fairly healthy. Some forested areas provide good wildlife habitat within an urbanized landscape. No evidence of pollution, fish kills, or stressed vegetation was observed. Urban trash and litter (tires, boards, bottles, cans, paper, plastic) were common in the unnamed tributary and scattered throughout the floodplains.

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 INTRODUCTION

The nature and extent of environmental contamination for Area A media other than groundwater are discussed in this section. As noted in Section 2.0, environmental investigations in Area A were initiated in 1989 and included several RI investigations (Phases I, II and III), supplemental investigations, and verification sampling during the Area A soil removal actions. The nature and extent of contamination as defined by the Phase III RI were described in the Phase III RI Report (B&R Environmental, 1996a). The following discussion summarizes the distribution and concentration of contaminants in site media that remained following the Area A removal actions and is based on the concentrations detected in those soil samples that were not removed during the excavation activities.

The validated data generated during the RI work and subsequent investigations provide the basis for this information. The analytical database for all samples is contained within Appendix A.

4.2 SITE 1

During the Phase I RI work, only cinders were detected in confirmation soil borings conducted near Site 1. This waste may represent the regraded remains of material from the burn pit, although no distinct scorched soil horizon was encountered. The Phase I borings were drilled through most of the suspected sources in the vicinity of Site 1. An area of clean fill was detected between the base fence line and the westernmost concrete lagoon (see Figure 4-1). The thickness of fill material at Site 1 averaged between 4 and 5 feet. The average thickness of waste-containing material was between 5 and 6 feet.

During Phase III, five of the seven test pits excavated at Site 1 showed the presence of a layer of multi-colored silty clay. This may represent buried sludges that were relocated from the Impoundment Area. These test pits were generally located between the western and central portions of the site (see Figure 2-8). No elevated HNu readings were obtained in any test pit. Wood and cinders were observed in two of the pits. Plywood, fabric, and many blankets were seen in one test pit (TP01-01-07), which was located in the center of the site.

In addition to the test pits, seven hand-augered soil borings and nine hand-augered confirmation borings were installed at Site 1 during the Phase III RI. Subsurface soil samples were collected for chemical analysis from borings. The multi-colored silty clay was seen in four of the seven soil borings; only one boring had a slightly elevated HNu reading of 1 ppm. The soil borings were also located between the

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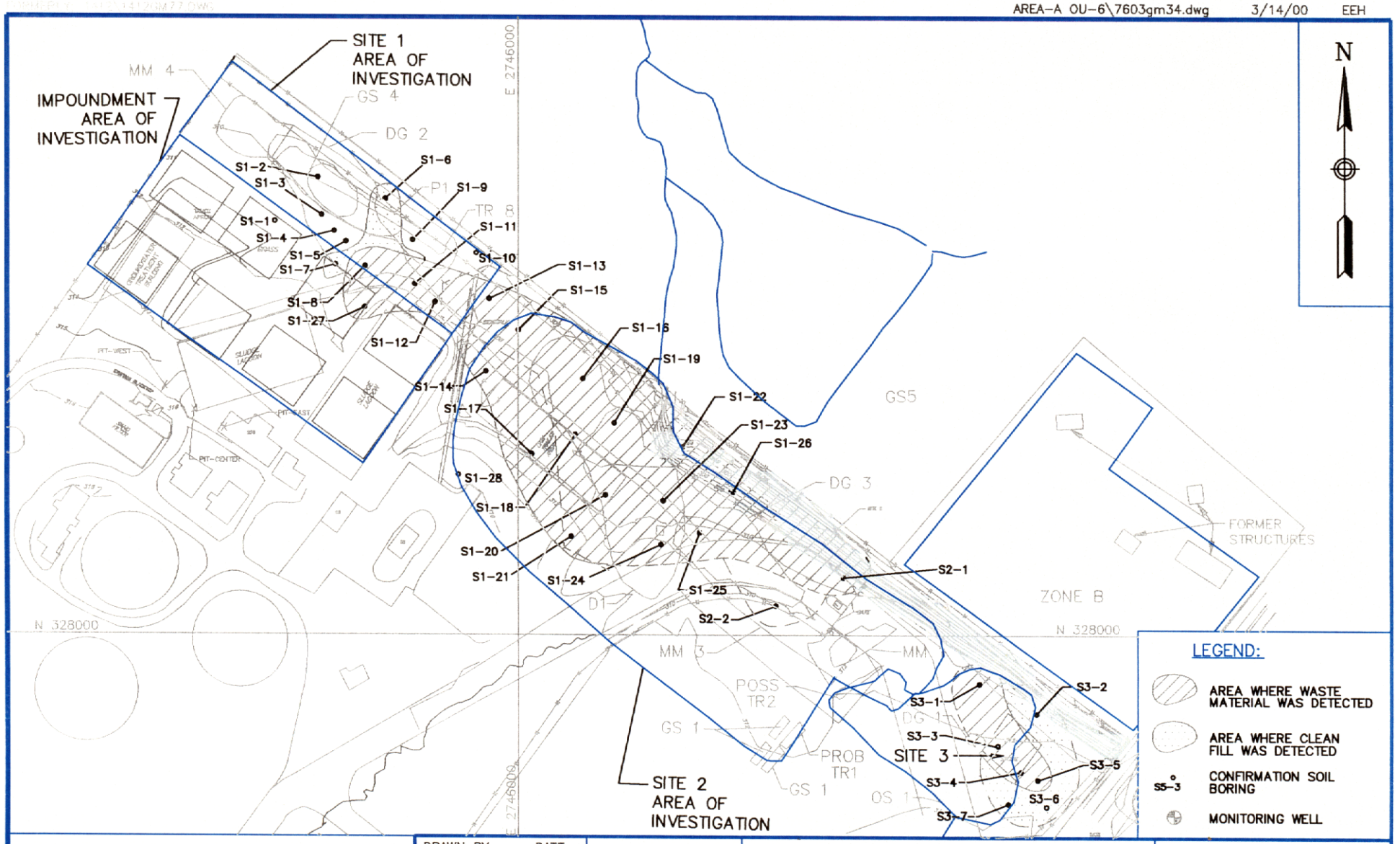

DRAWN BY EEH	DATE 3/14/00	Tetra Tech NUS, Inc.	CONFIRMATION BORING RESULTS PHASE I – SITES 1,2 AND 3 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO.	7603
OWNER NO.	0601
APPROVED BY	DATE
DRAWING NO.	FIGURE 4-1
REV.	

7603gm34.dwg

western and central portions of the site. Two soil borings located in the eastern section of the site had slightly elevated HNu readings of 1 and 4 ppm, but they did not contain the multi-colored silty clay. Figure 2-8 details the Phase III soil boring locations.

Nine confirmation borings were drilled at Site 1 during Phase III to better define the extent of the silty clay. These were placed surrounding the known area of the silty clay after the test pits and soil borings were excavated or drilled. Only one location revealed the presence of the silty clay located in the central section of Site 1. Although the silty clay appears to include the approximate location of EPIC feature TR8 and a large portion of MM4, it does not extend past the base fenceline to the north nor does it extend to the Impoundment Area. These results suggest the presence of buried sludges, which were relocated from the former Impoundment Area.

Appendix D contains the soil boring logs for Site 1. Test pit logs are contained in Appendix E.

4.2.1 Site 1 Geophysical Survey Results

4.2.1.1 Phase III EM Survey

The Phase III EM survey in the vicinity of Site 1 revealed only one significant anomaly not related to known utility lines or other cultural features. This anomaly was observed as a slight increase in the inphase response near the northernmost corner of Area A (Figure 4-2). The anomaly was located along profile lines 40 and 60 from stations 15 to 55 and along profile line 80 from stations 15 to 50. The maximum inphase response was between 6 and 8 parts per thousand (ppt), recorded along profile line 60. The anomaly was present in the inphase response only and may indicate the possible presence of buried metallic waste. The location of this anomaly correlates well with the Navy-surveyed location of aerial photo feature MM4 from the EPIC analysis (Figure 4-3). The Phase III EM survey results are detailed in Appendix B.

4.2.1.2 Post-Removal Magnetic and EM Surveys

Supplemental magnetic and EM surveys were conducted in the vicinity of Sites 1 and 2 during the 1998 removal action. The purpose of the geophysical surveys was to locate any remaining buried drums and other ferrous metal objects and to clear drilling locations for the Area A extraction well network. Detailed information regarding the surveys is presented in a TtNUS December 1998 letter report (TtNUS, 1998n). The complete results of the supplemental surveys are outlined in Appendix B.

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NOTE: COLOR CONTOUR MAP OF IN-PHASE (METAL DETECTION) DATA FROM MARCH 1995
UNITS: PARTS PER THOUSAND

0 150 300
SCALE IN FEET

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CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY Tea DATE 4/27/00
DRAWING NO. FIGURE 4-2 REV.

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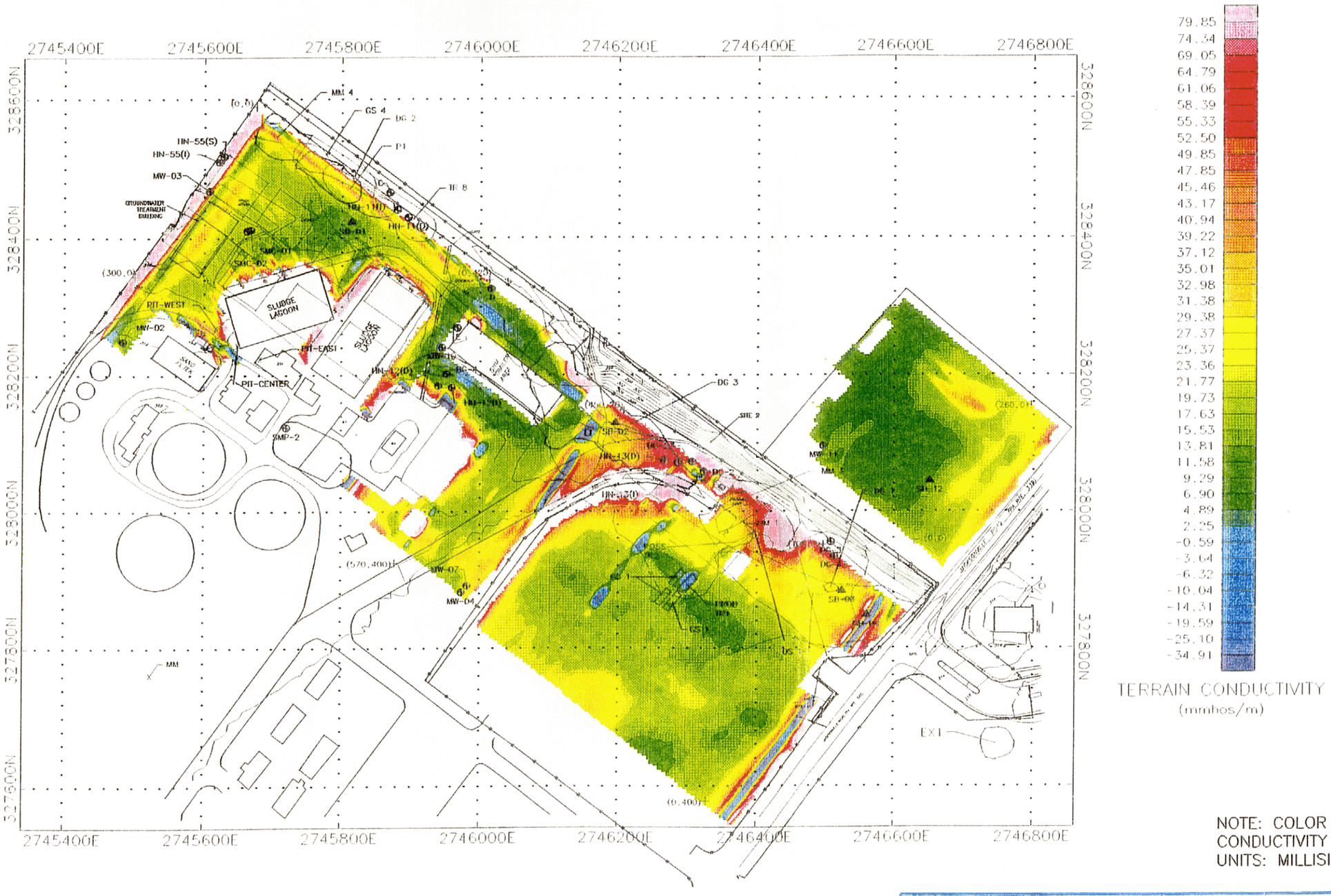
7603gm06.dwg



NOTE: COLOR CONTOUR MAP OF TERRAIN CONDUCTIVITY DATA FROM MARCH 1995
UNITS: MILLISIEMENS PER METER

0 150 300
SCALE IN FEET

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CHECKED BY DATE			OWNER NO. 7603
REVISED BY DATE			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-3 REV.

Based on the supplemental surveys, four anomalous zones were identified in the vicinity of Sites 1 and 2. In addition, about 20 isolated anomalies were also identified (TtNUS, 1998n). Figure 4-4 details the four anomalous zones and the isolated anomalies.

Anomalous Zone 1 begins near the Site 1 and Site 2 boundary. A former walkway is present on the eastern edge of this zone. The cause of this zone may be associated with possible lighting foundations, the sidewalk itself, and associated metallic objects.

Isolated anomalies indicated by "Xs" on the anomaly map generally were detected by both magnetic and electromagnetic instrumentation. The size and strength of these anomalies likely represent small metallic objects and not steel drums or drum remnants. The report on the supplemental surveys recommended that the anomalies be ground-checked to determine if surface features may have caused the associated geophysical responses.

4.2.2 Site 1 Soil Gas Survey Results

The most recent soil gas survey at Site 1 was conducted as part of the Phase III RI work scope. No additional surveys were conducted subsequent to that work. As outlined in the Phase III RI Report (B&R Environmental, 1996a), significant soil gas results for Site 1 (Figures 4-5, 4-6 and 4-7) were as follows:

- Elevated VOCs were detected in several soil gas samples near and within Site 1. Chemicals frequently detected included PCE, TCE, cis-1,2-DCE, carbon tetrachloride (CCl_4), and ethylbenzene.
- Soil gas samples near well cluster HN-11 frequently showed CCl_4, TCE, and PCE within 100 feet of the northern base boundary. This area generally exhibited the highest individual VOC concentrations within the EPIC features for Site 1.
- TCE was detected in soil gas samples between the buried impoundment area and Site 1, particularly between IM3, IM4, and P1/GS1. The highest TCE concentration was 24 ug/l. TCE was not found in samples from the vicinity of MM4 and the western end of TR8.
- PCE was detected at low levels ranging from 0.09J to 0.86J ug/l throughout Site 1.
- Some VOCs were found in soil gas samples taken from just north of the base fenceline in this area.
- Although benzene was not detected in samples from this area, other BTEX compounds were detected in nine soil gas samples from the vicinity of Site 1. Positive concentrations ranged from 5.9 to 37 ug/l.

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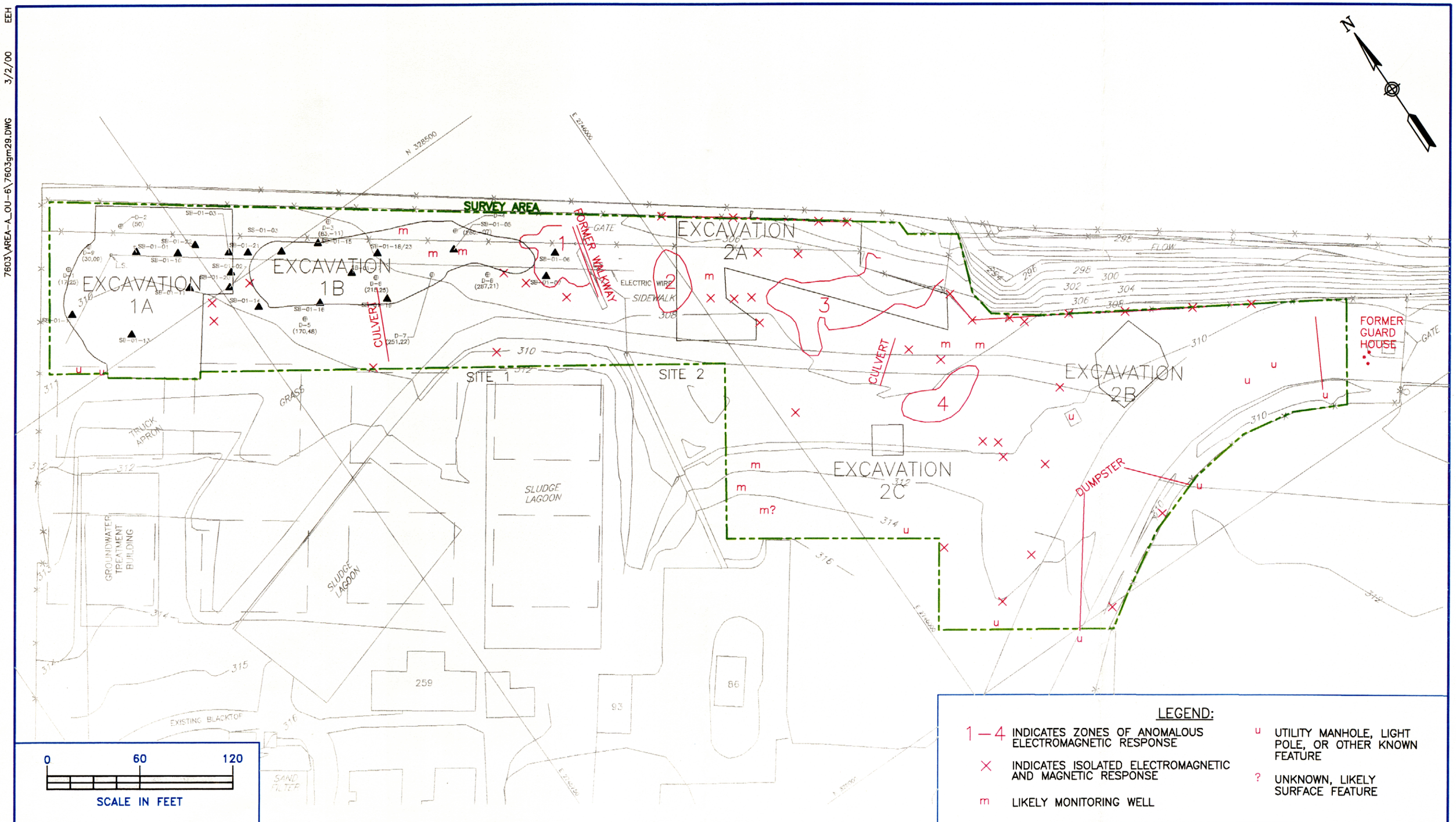

LEGEND:

1 — 4 INDICATES ZONES OF ANOMALOUS ELECTROMAGNETIC RESPONSE

× INDICATES ISOLATED ELECTROMAGNETIC AND MAGNETIC RESPONSE

m LIKELY MONITORING WELL

u UTILITY MANHOLE, LIGHT POLE, OR OTHER KNOWN FEATURE

? UNKNOWN, LIKELY SURFACE FEATURE

No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	OHM TRAILER AREA REMOVED.	LDL			

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REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

GEOPHYSICAL SURVEY ANOMALIES
SITES 1 AND 2
FORMER NAWC WARMINSTER
WARMINSTER, PA

CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY Tea DATE 4/23/00
DRAWING NO. FIGURE 4-4 REV. 1

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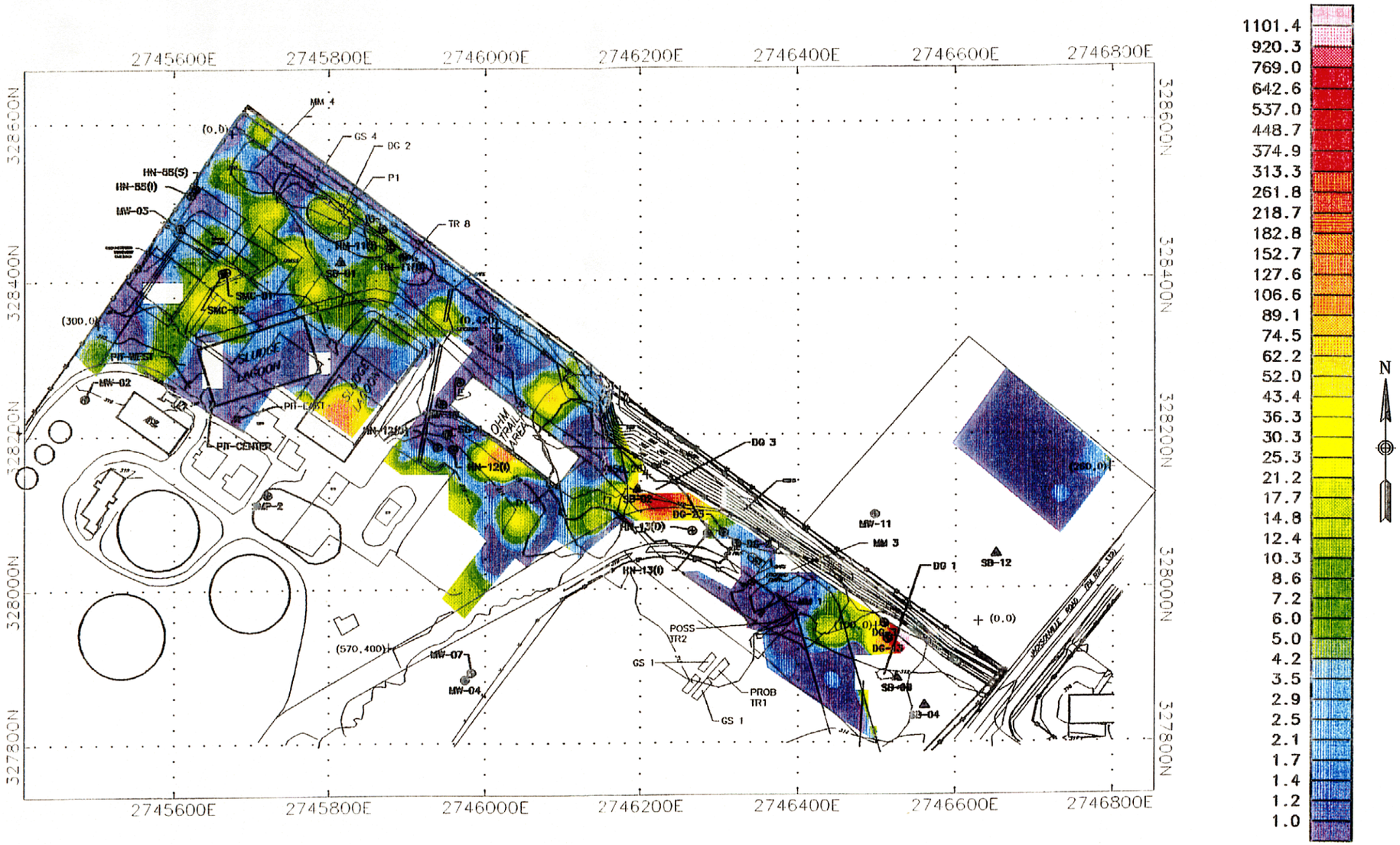

1101.4
920.3
769.0
642.6
537.0
448.7
374.9
313.3
261.8
218.7
182.8
152.7
127.6
106.6
89.1
74.5
62.2
52.0
43.4
36.3
30.3
25.3
21.2
17.7
14.8
12.4
10.3
8.6
7.2
6.0
5.0
4.2
3.5
2.9
2.5
2.1
1.7
1.4
1.2
1.0

SOIL GAS DATA
(ug/L)

N

0 150 300
SCALE IN FEET

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REVISED BY DATE			APPROVED BY Lea DATE 4/23/00
SCALE AS NOTED			DRAWING NO. FIGURE 4-5 REV.

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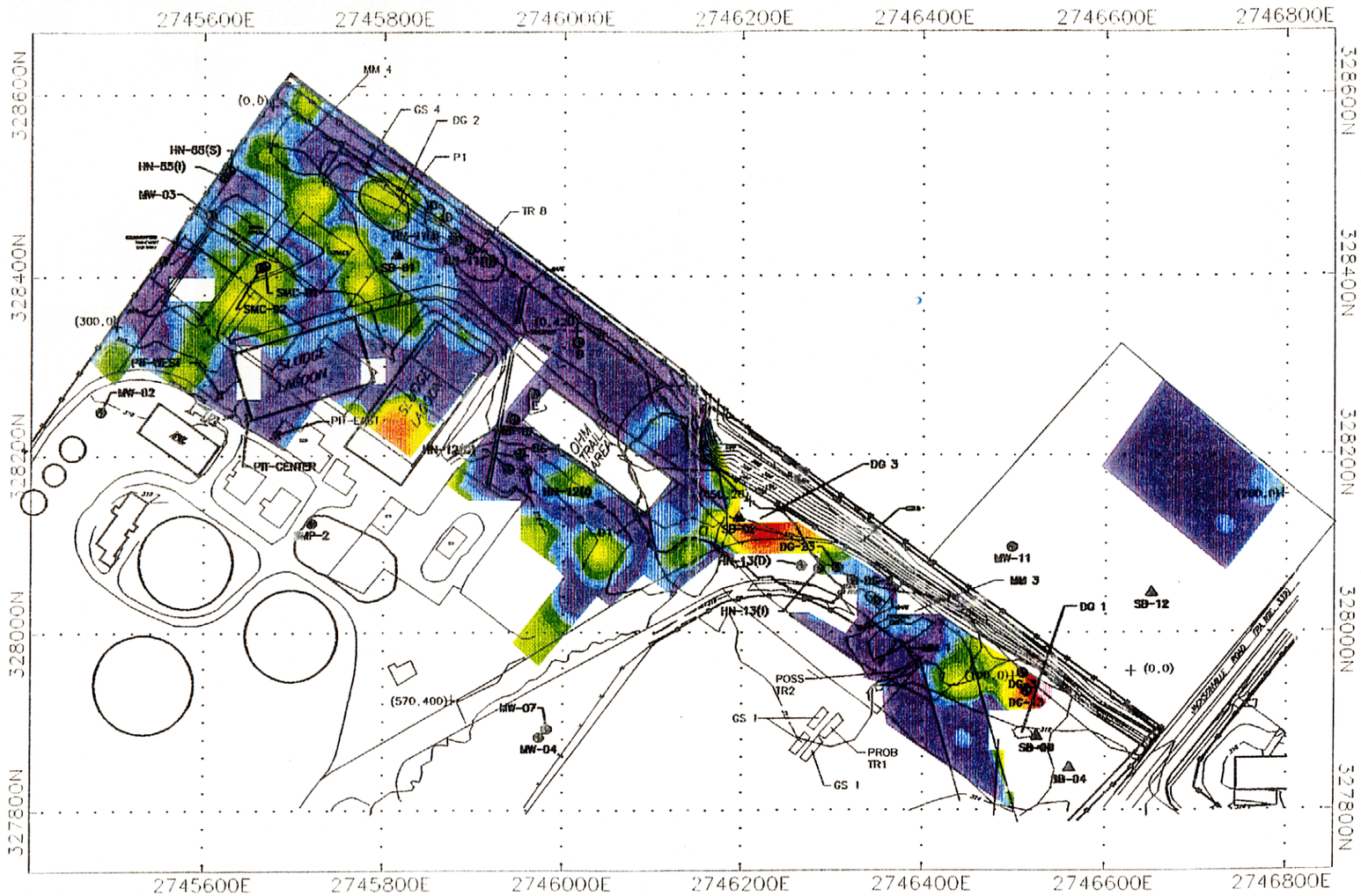

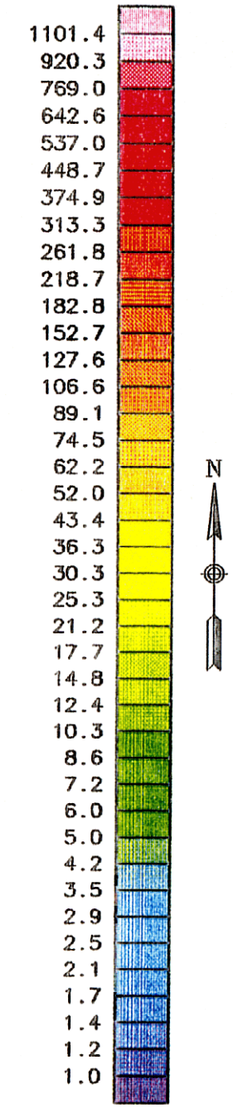

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SCALE IN FEET

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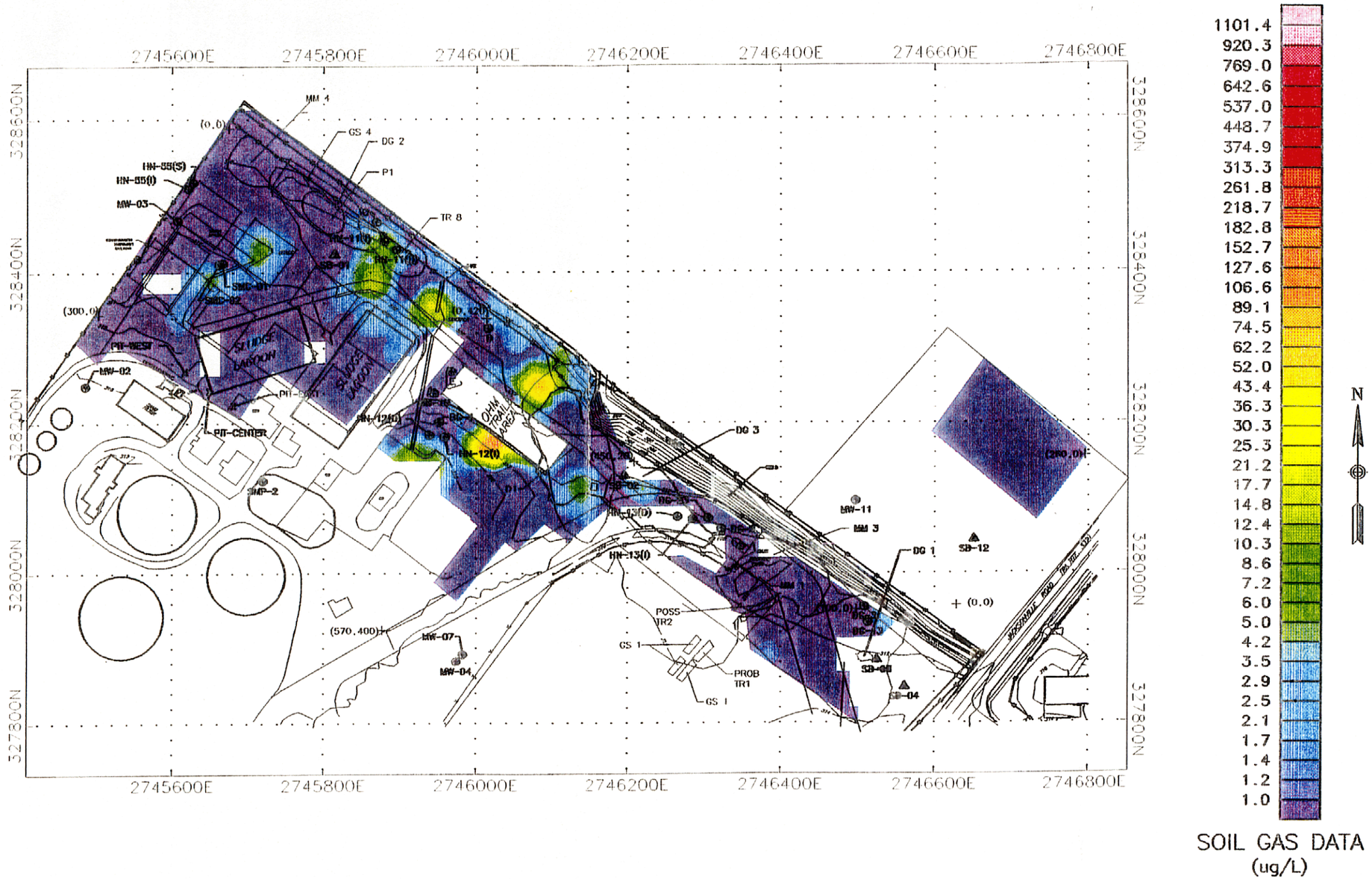
CONTRACT NO. N62472-90-D-1298

OWNER NO. 7603

APPROVED BY KEA DATE 4/23/00

DRAWING NO. FIGURE 4-6 REV.



SOIL GAS DATA (ug/L)
1101.4
920.3
769.0
642.6
537.0
448.7
374.9
313.3
261.8
218.7
182.8
152.7
127.6
106.6
89.1
74.5
62.2
52.0
43.4
36.3
30.3
25.3
21.2
17.7
14.8
12.4
10.3
8.6
7.2
6.0
5.0
4.2
3.5
2.9
2.5
2.1
1.7
1.4
1.2
1.0

0 150 300
SCALE IN FEET

DRAWN BY EEH	DATE 3/14/00	Tetra Tech NUS, Inc.	VOC SOIL GAS RESULTS EXCLUSIVE OF BTEX AREA A PHASE III RI FORMER NAWC WARMINSTER WARMINSTER, PA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. N62472-90-D-1298
OWNER NO. 7603
APPROVED BY TDa DATE 4/23/00
DRAWING NO. FIGURE 4-7
REV.

- Higher VOC levels generally were found in the deeper soil gas samples taken at each soil gas location.

Detailed results of the soil gas survey are contained in Appendix C.

4.2.3 Site 1 Surface Soil Results

4.2.3.1 Pre-Removal Sample Results

Tables 4-1 and 4-2 provide the occurrence and distribution of inorganics and organics in background and site-related surface soil samples collected during the Phase III RI. The average depth of the Area A surface soil samples, as noted in Section 2.0, was between 6 and 30 inches. The pre-removal results included those samples collected up to and including 1996; the post-removal results included those samples collected to better define the soil excavation areas, as well as the removal action verification samples.

As part of the Phase III RI, a risk assessment was conducted for Area A (B&R Environmental, 1996a). The objectives of the risk assessment were to define the actual or potential risks to human health and the environment resulting from the presence of contamination in surface water, surface soil, subsurface soil, and sediment and to provide the basis for determining appropriate remedial measures. For Site 1 surface soils, the identified exposure routes included incidental ingestion of, dermal contact with, and inhalation of fugitive dust via surface soil for current industrial employees and future residents. Four compounds identified during the sampling activities were selected as COCs for Site 1 surface soils: 1,2,3,7,8-PECDD, Aroclor 1248, OCDD, and Aroclor 1260. Based on the risk analysis, the total cancer risks (exposure to COCs via all three pathways) for the current industrial and future residential receptors were within the 1.0E-04 to 1.0E-06 target risk range. Therefore, no removal actions for surface soils within Site 1 were proposed.

4.2.3.2 Post-Removal Sample Results

During the excavation of subsurface soils at Site 1 in 1998, the surface soils were excavated from excavation areas 1A and 1B, stockpiled, and later used as backfill. Figure 4-8 details the post-removal surface soil sample locations. Table 4-3 provides the occurrence and distribution of organics and inorganic compounds in the surface soil sample (SS-01-06) present at Site 1 following the removal action. Analytical data (Appendix A) from the surface soil sample were compared to both federal and state soil screening criteria for an industrial exposure scenario. The intended future use of Site 1 is industrial. As noted in Section 2.0, federal soil screening criteria included EPA Region III Risk-Based Concentration

TABLE 4-1

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SITE 1 SURFACE SOIL

NAWC WARMINSTER, PENNSYLVANIA

(mg/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
ALUMINUM	31 / 31	4780 - 18100	15282	6 / 6	15100 - 22600	19526
ARSENIC	27 / 31	0.28 - 12.1	10.50	5 / 5	4.1 - 7.2	6.99
BARIUM	27 / 29	34.1 - 225	74.12	5 / 5	61.9 - 101	101
BERYLLIUM	27 / 31	0.31 - 1.7	0.90	5 / 5	0.97 - 1.2	1.2
CADMIUM	0 / 31	-	-	2 / 5	2.7 - 3.4	3.4
CALCIUM	25 / 29	240 - 1910	773	5 / 5	884 - 2800	2800
CHROMIUM	31 / 31	7.9 - 35.3	21.59	6 / 6	28.1 - 263	263
COBALT	27 / 30	1.6 - 22.1	10.32	6 / 6	9.6 - 15.3	14.27
COPPER	29 / 31	3.6 - 30.6	13.56	5 / 5	6.3 - 23.4	23.4
CYANIDE	0 / 21	-	-	3 / 6	2.1 - 3.6	3.6
IRON	31 / 31	6980 - 410500	54527	6 / 6	21800 - 31300	30442
LEAD	31 / 31	1.6 - 96.5	16.69	6 / 6	11.8 - 35.1	28.71
MAGNESIUM	27 / 31	518 - 4960	2472	5 / 5	2040 - 3170	3042
MANGANESE	31 / 31	30.9 - 2010	527.88	6 / 6	421 - 816	816
MERCURY	1 / 28	0.37	0.06	1 / 6	0.07	0.05
NICKEL	20 / 27	4.1 - 21.7	14.40	6 / 6	12.7 - 17.2	16.44
POTASSIUM	27 / 29	89.1 - 3050	886	6 / 6	675 - 2450	2266
SILVER	0 / 17	-	-	3 / 6	5.6 - 17	17
THALLIUM	3 / 31	0.37 - 0.42	0.42	1 / 6	1	0.90
VANADIUM	31 / 31	15.4 - 45	33.01	6 / 6	28.2 - 37.4	36.51
ZINC	27 / 29	9 - 60	31.34	5 / 5	39.8 - 82.2	67.43

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TAB 2

OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 1 SURFACE SOIL
NAWC WARMINSTER, PENNSYLVANIA
(ug/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
1,2,3,4,6,7,8-HPCDD	0 / 3	-	-	3 / 5	0.06 - 0.35	0.35
1,2,3,4,7,8-HXCDF	0 / 3	-	-	1 / 5	0.0033	0.0011
1,2,3,6,7,8-HXCDD	0 / 3	-	-	2 / 5	0.0027 - 0.01	0.01
1,2,3,6,7,8-HXCDF	0 / 3	-	-	1 / 5	0.0041	0.0041
1,2,3,7,8-PECDD	0 / 3	-	-	2 / 5	0.01	0.0094
OCDD	0 / 3	-	-	5 / 5	2.03 - 8.38	8.38
AROCLOR-1248	0 / 21	-	-	1 / 6	370	195.88
AROCLOR-1260	0 / 21	-	-	2 / 6	16 - 100	59.79
BENZO(A)PYRENE	0 / 11	-	-	1 / 6	47	47
BENZO(B)FLUORANTHENE	1 / 11	58	58	1 / 6	75	75
BENZO(G,H,I)PERYLENE	0 / 11	-	-	1 / 6	43	43
CHRYSENE	1 / 11	51	51	1 / 6	66	66
FLUORANTHENE	1 / 11	92	92	3 / 6	44 - 73	73
PYRENE	1 / 11	100	100	3 / 6	44 - 77	77
BENZENE	0 / 20	-	-	1 / 6	2	2
CHLOROBENZENE	0 / 20	-	-	1 / 6	2	2
TOLUENE	3 / 20	2	2	1 / 6	2	2

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4-3

OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 1 SURFACE SOIL (POST-REMOVAL)

NAWC WARMINSTER, PENNSYLVANIA

Compound	Background Data				Site-Related Data				
	Frequency of Detection	Range of Positive Detections* Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections* Min - Max	Mean of All Data	Sampling Round and Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	1/1	16,600	16,600.00	SS-01-06	16,600
CHROMIUM	29/29	7.9 J - 35.3 J	BG-12	21.7	1/1	28.1	28.10	SS-01-06	28.1
COBALT	25/29	1.6 - 22.1	BG-23-DUP	10.4	1/1	11	11.00	SS-01-06	11
IRON	29/29	6980 - 410500	BG-04	35,030	1/1	24,300	24,300.00	SS-01-06	24,300
LEAD	29/29	1.6 J - 96.5 J	BG-13	16.4	1/1	11.8	11.80	SS-01-06	11.8
MANGANESE	29/29	30.9 - 2010	BG-28	604	1/1	512	512.00	SS-01-06	512
NICKEL	18/29	4.1 J - 21.7 J	BG-23-DUP	11.1	1/1	12.8	12.80	SS-01-06	12.8
POTASSIUM	25/29	89.1 - 3050	BG-24	997	1/1	892	892.00	SS-01-06	892
VANADIUM	29/29	15.4 - 45	BG-12	32.2	1/1	34.7	34.70	SS-01-06	34.7
BENZENE	0/19				1/1	2	2.00	SS-01-06	2
CHLOROBENZENE	0/19				1/1	2	2.00	SS-01-06	2
TOLUENE	3/19	2	BG-17, BG-21, BG-22	2	1/1	2	2.00	SS-01-06	2

Notes:

* - Minimum and maximum detected site-related concentrations are based on duplicate samples.

Units are mg/kg for inorganics, ug/kg for organics.

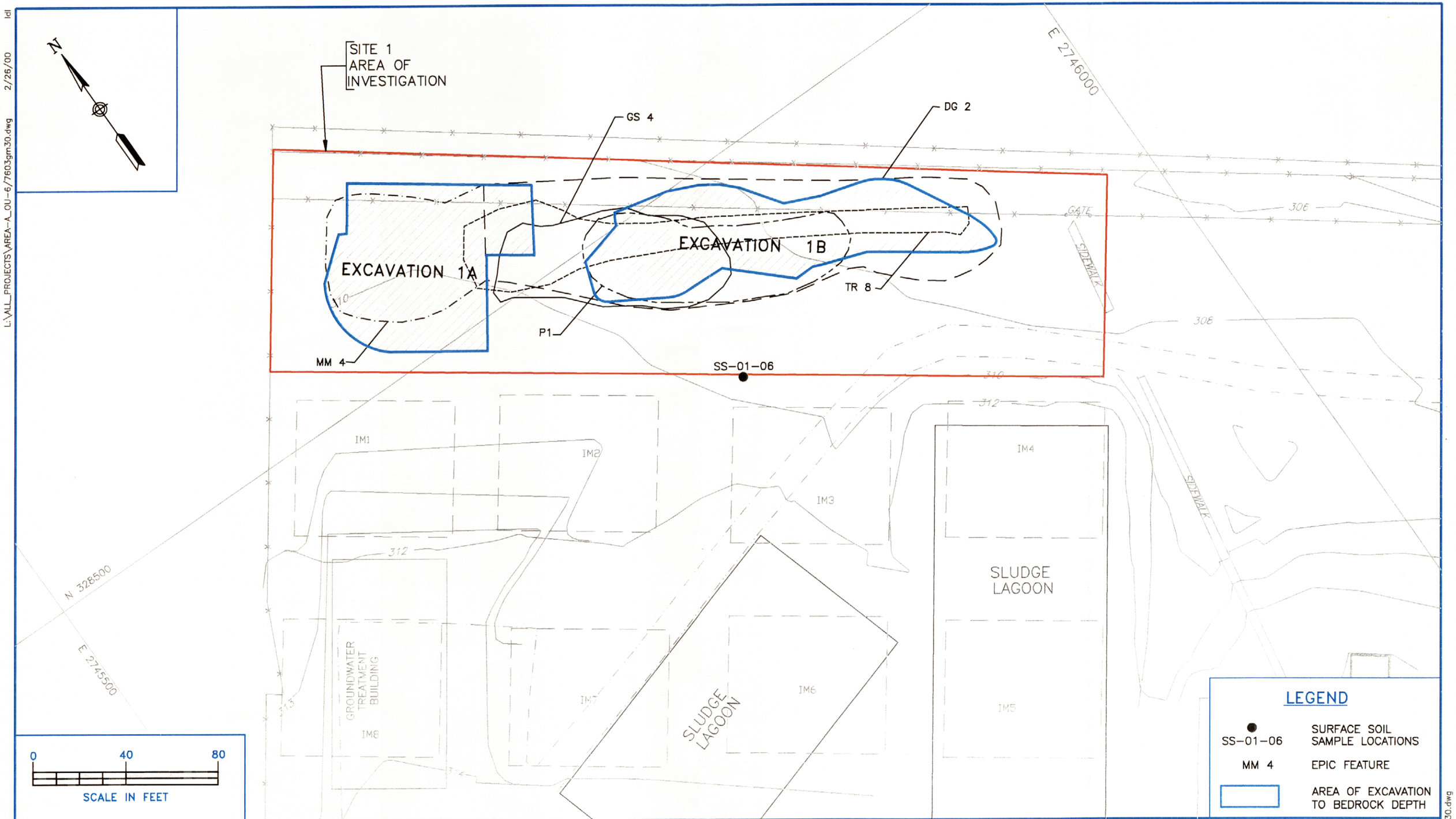
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.

Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.

The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.

Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.

Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	SURFACE SOIL SAMPLES REVISED.	LDL			

DRAWN BY LDL DATE 2/26/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SURFACE SOIL SAMPLE LOCATION MAP

AREA A – SITE 1

FORMER NAWC WARMINSTER

WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY TRa DATE 4/23/00
DRAWING NO. FIGURE 4-8
REV. 1

L:\ALL_PROJECTS\AREA-A_OU-6/7603gm30.dwg 2/26/00 ldl

AREA-A_OU-6/7603gm30.dwg

442 B17Y

(RBC) Tables (EPA, 1999b). State of Pennsylvania criteria were obtained from the Statewide Health Standard Tables, Subchapter C, section 250.312 of the PA Land Recycling Program Regulations. No exceedances of the criteria were present in the remaining Site 1 surface soil sample.

4.2.4 Site 1 Subsurface Soil Results

4.2.4.1 Pre-Removal Sample Results

Based on the results obtained from the Phase III RI, the Navy conducted a removal action of certain subsurface soils from Site 1. Subsurface soils were defined as those at depths generally greater than 2 feet from the ground surface. In Site 1, the subsurface soil sample depths (i.e., top of sample interval) ranged from 2.5 feet bgs to 12 feet. Samples were collected from soil borings (i.e., split-spoon samples) and test pit excavations, as discussed in Section 2.0 of this report. The purpose of this action was to remediate soils contaminated primarily with antimony, cadmium, and TCE. Tables 4-4 and 4-5 detail the occurrence and distribution of inorganic and organic compounds in background and Site 1 subsurface soils prior to the 1998 removal action. The removal action, including determination of clean-up goals, is detailed in the following reports:

- Removal Site Evaluation Report for Area A Soils; April 1998 (B&R Environmental, 1998a)
- Post Removal Summary Report, Area A, Sites 1, 2, and 3; May 1999 (TtNUS, 1999a)

Figure 4-9 outlines those areas within Site 1 in which subsurface soils were excavated and disposed off site.

4.2.4.2 Post-Removal Sample Results

Table 4-6 presents the occurrence and distribution of organics and inorganics in background and Site 1 subsurface soil samples that remained after the 1998 removal action. Analytical data obtained from the analysis of the Site 1 post-removal subsurface soil samples were compared to federal and state soil screening criteria for industrial exposure scenario. Figure 4-10 details those post-removal subsurface sample locations where contaminant concentrations exceeded both the highest observed background concentration for that contaminant and one of the screening criteria, as shown on the analytical summary tables contained in Appendix A. Arsenic was the only detected compound that exceeded the maximum background and screening criteria. In samples SB-01-13 and SB-01-14, arsenic was detected at 12.8 mg/kg and 25.5 mg/kg, respectively. Samples SB-01-13 and SB-01-14 are from the same boring location in the northwestern corner of Site 1. Sample SB-01-13 was collected from a depth of 4 to 5 feet bgs and

TABLE 4-4

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SITE 1 SUBSURFACE SOIL

NAWC WARMINSTER, PENNSYLVANIA

(mg/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
ALUMINUM	31 / 31	4780 - 18100	15282	13 / 13	2910 - 33500	15446
ANTIMONY	1 / 22	13.6 - 13.6	4.65	6 / 9	88.3 - 376	376
ARSENIC	27 / 31	0.28 - 12.1	10.50	11 / 11	1.7 - 8.8	4.89
BARIUM	27 / 29	34.1 - 225	74.12	13 / 13	57.5 - 375	251.80
BERYLLIUM	27 / 31	0.31 - 1.7	0.90	12 / 13	0.35 - 1.5	1.09
CADMIUM	0 / 31	-	-	8 / 13	0.52 - 699	240.34
CALCIUM	25 / 29	240 - 1910	772.86	13 / 13	420 - 115000	115000
CHROMIUM	31 / 31	7.9 - 35.3	21.59	12 / 12	10.3 - 18100	8004
COBALT	27 / 30	1.6 - 22.1	10.32	13 / 13	11.1 - 64.1	38.62
COPPER	29 / 31	3.6 - 30.6	13.56	13 / 13	1.7 - 462	160.80
CYANIDE	0 / 21	-	-	8 / 13	1.6 - 237	99.53
HEXAVALENT CHROMIUM	0 / 9	-	-	3 / 6	5.5 - 24.2	18.81
IRON	31 / 31	6980 - 410500	54527	13 / 13	11500 - 337000	181608
LEAD	31 / 31	1.6 - 96.5	16.69	13 / 13	3.7 - 430	176.83
MAGNESIUM	27 / 31	518 - 4960	2472	13 / 13	976 - 4910	3242
MANGANESE	31 / 31	30.9 - 2010	527.88	13 / 13	347 - 2630	1254
MERCURY	1 / 28	0.37	0.06	8 / 13	0.095 - 3.5	1.59
NICKEL	20 / 27	4.1 - 21.7	14.40	4 / 5	10.7 - 57.6	40.15
POTASSIUM	27 / 29	89.1 - 3050	886.09	11 / 11	65.8 - 2590	1239
SILVER	0 / 17	-	-	9 / 13	2.1 - 389	389
SODIUM	5 / 20	55.2 - 86.7	86.7	5 / 6	17.2 - 64.3	64.30
VANADIUM	31 / 31	15.4 - 45	33.01	8 / 13	8 - 66.6	22.53
ZINC	27 / 29	9 - 60	31.34	13 / 13	11.8 - 1950	776.62

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 1 SUBSURFACE SOIL
NAWC WARMINSTER, PENNSYLVANIA
(ug/kg)

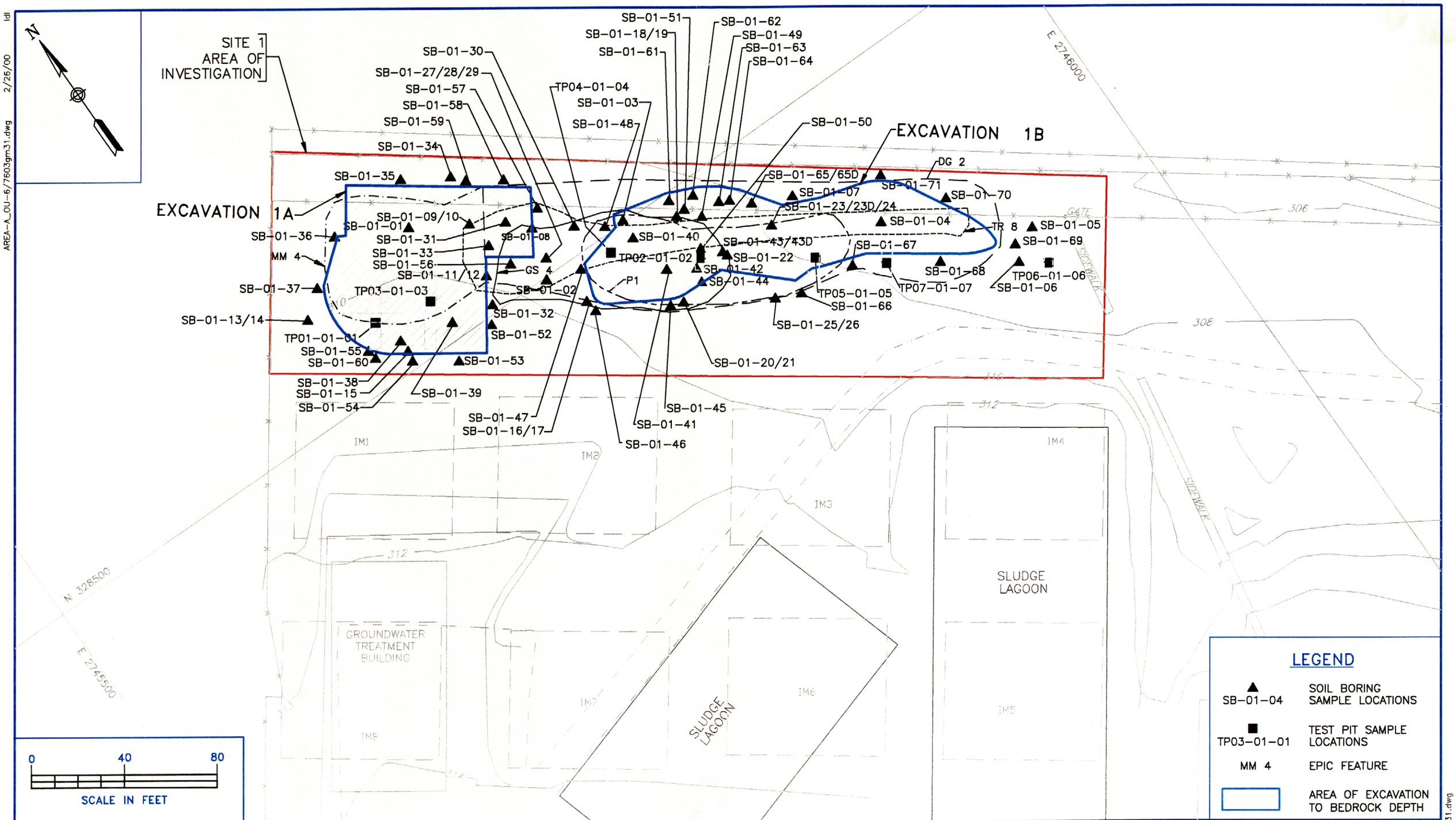
SUBSTANCE	BACKGROUND		BACKGROUND	SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
4,4'-DDD	1 / 21	16	3.81	3 / 6	26 - 69	69
4,4'-DDE	1 / 21	820	108.13	3 / 6	4.3 - 13	10.45
4,4'-DDT	1 / 21	1440	188.58	3 / 6	15 - 240	125.01
ALDRIN	0 / 21	-	-	1 / 6	67	34.42
ALPHA-CHLORDANE	0 / 21	-	-	2 / 6	4.3 - 41	21.69
AROCLOR-1254	1 / 21	51	51	2 / 6	27 - 4200	2126
AROCLOR-1260	0 / 21	-	-	3 / 6	490 - 1400	1400
ENDOSULFAN SULFATE	0 / 21	-	-	1 / 6	12	7.61
ENDRIN	0 / 21	-	-	2 / 5	4.8 - 290	183.07
ENDRIN ALDEHYDE	0 / 21	-	-	2 / 5	5.2 - 14	14
ENDRIN KETONE	0 / 21	-	-	2 / 6	13 - 30	18.24
GAMMA-CHLORDANE	0 / 21	-	-	1 / 6	4.8	3.14
METHOXYCHLOR	0 / 21	-	-	1 / 6	45	29.98
ACENAPHTHENE	0 / 11	-	-	1 / 7	1200	710.94
ANTHRACENE	0 / 11	-	-	1 / 7	2700	1328
BENZ(A)ANTHRACENE	0 / 11	-	-	5 / 7	88 - 5400	2377
BENZO(A)PYRENE	0 / 11	-	-	5 / 7	85 - 5000	2201
BENZO(B)FLUORANTHENE	1 / 11	58	58	5 / 7	130 - 6000	2648
BENZO(G,H,I)PERYLENE	0 / 11	-	-	4 / 7	69 - 3300	1532
BENZO(K)FLUORANTHENE	1 / 11	46	46	5 / 7	57 - 2000	914.75
BIS(2-ETHYLHEXYL)PHTHALATE	1 / 11	50	50	4 / 7	40 - 270	270
CARBAZOLE	0 / 11	-	-	1 / 7	1300	750.92
CHRYSENE	1 / 11	51	51	5 / 7	110 - 5700	2498
DI-N-BUTYL PHTHALATE	0 / 11	-	-	1 / 7	70	70
DIBENZOFURAN	0 / 11	-	-	1 / 7	950	613.39
FLUORANTHENE	1 / 11	92	92	5 / 7	160 - 16000	6888
FLUORENE	0 / 11	-	-	1 / 7	1400	791.24
INDENO(1,2,3-CD)PYRENE	0 / 11	-	-	4 / 7	59 - 2900	1360
PYRENE	1 / 11	100	100	5 / 7	130 - 11000	4775
1,2-DICHLOROETHENE (TOTAL)	0 / 20	-	-	1 / 14	6	6
2-BUTANONE	0 / 20	-	-	1 / 14	63	19.42
ACETONE	4 / 19	8 - 12	12	1 / 4	270	227
TETRACHLOROETHENE	0 / 20	-	-	1 / 14	6	6
TRICHLOROETHENE	0 / 20	-	-	2 / 14	3 - 73	21.12

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4-6
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 1 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Substance	Frequency of Detection	Range of Positive Detections Min - Max	Sampling Round and Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Sampling Round and Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	17/17	5580 - 33500	15,852	SB-01-05	18,710
ANTIMONY	1/29	13.6 J	BG-16	4.11	9/30	0.31 - 15.2	1.91	SB-01-48	3.60
ARSENIC	25/29	0.28 - 12.1 J	BG-11	11.7	16/17	1.3 - 25.5	5.12	SB-01-14	8.32
BARIUM	25/29	34.1 - 225	BG-28	87.1	17/17	26.4 - 210	93	SB-01-02	130
BERYLLIUM	25/29	0.31 - 1.7 J	BG-23-DUP	0.88	15/17	0.41 - 3.1	1.40	SB-01-14	2.03
CADMIUM	0/29				23/40	0.05 - 61.4	6.01	SB-01-25	15.5
CALCIUM	23/29	240 - 1910	BG-24	781	17/17	314 - 53400	4,220	SB-01-25	5,468
CHROMIUM	29/29	7.9 J - 35.3 J	BG-12	21.7	38/39	7 - 4600	250	SB-01-48	233
COBALT	25/29	1.6 - 22.1	BG-23-DUP	10.4	16/17	7.1 - 66.1	17.2	SB-01-25	25.8
COPPER	27/29	3.6 J - 30.6	BG-29	14.1	17/17	2.5 - 299	65.7	SB-01-28	299
CYANIDE	0/20				1/5	1.6	0.69	SB-01-05	1.60
IRON	29/29	6980 - 410500	BG-04	35,030	17/17	9560 - 251000	38,462	SB-01-25	53,412
LEAD	29/29	1.6 J - 96.5 J	BG-13	16.4	24/24	2.1 - 135	19.7	SB-01-25	31.3
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	17/17	380 - 5890	3,084	SB-01-16	5,890
MANGANESE	29/29	30.9 - 2010	BG-28	604	17/17	230 - 2630	848	SB-01-02	1,264
MERCURY	1/29	0.37	BG-23	0.05	7/17	0.1 - 6.8	0.47	SB-01-25	0.46
NICKEL	18/29	4.1 J - 21.7 J	BG-23-DUP	11.1	14/17	3.1 - 87.9	18.0	SB-01-25	28.6
POTASSIUM	25/29	89.1 - 3050	BG-24	997	13/17	320 - 4600	1,888	SB-01-21	4,600
SELENIUM	0/29				6/17	0.88 - 3.3	0.72	SB-01-25	1.29
SILVER	0/29				11/17	0.67 - 360	22.0	SB-01-25	17
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	15/17	17.2 - 707	134	SB-01-25	226
THALLIUM	3/29	0.37 - 0.42	BG-23-DUP	0.42	10/24	0.4 - 1.7	0.55	SB-01-25	0.69
VANADIUM	29/29	15.4 - 45	BG-12	32.2	17/17	13.8 - 66.6	30.1	SB-01-05	38.4
ZINC	25/29	9 - 60	BG-13	30.0	17/17	11.8 - 451	67.1	SB-01-25	104
2-BUTANONE	0/19				1/6	4.8	6.05	SB-01-30	4.80
4,4'-DDD	1/21	16 J	BG-12	2.98	1/2	55	28.5	SB-01-06-MAX	55.0
4,4'-DDE	1/21	820	BG-12	820	2/2	4.3 - 12	8.15	SB-01-06-MAX	12.0
4-METHYL-2-PENTANONE	0/19		BG-17, BG-21, BG-22		1/6	1.6	5.52	SB-01-30	1.60
AROCLOR-1254	1/21	51	BG-13	41.3	1/8	41	22.1	SB-01-06-MAX	27.1
BIS(2-ETHYLHEXYL)PHTHALATE	1/11	50 J	BG-16	50.0	1/8	40	175	SB-01-06-MAX	40.0
ENDRIN	0/21				1/2	4.8	3.43	SB-01-06-MAX	4.80
TOLUENE	3/19	2 - 2		2.0	1/6	2.9	4.82	SB-01-30	2.90

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.
Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/18/00	TITLE AND EXCAVATION AREA REVISED.	LDL			

DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL
SOIL EXCAVATION AREA
AREA A – SITE 1
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Tra DATE 4/23/00
DRAWING NO. FIGURE 4-9
REV. 1

ldl 2/26/00 AREA-A_OU-6/7603gm31.dwg

AREA-A_OU-6/7603gm31.dwg

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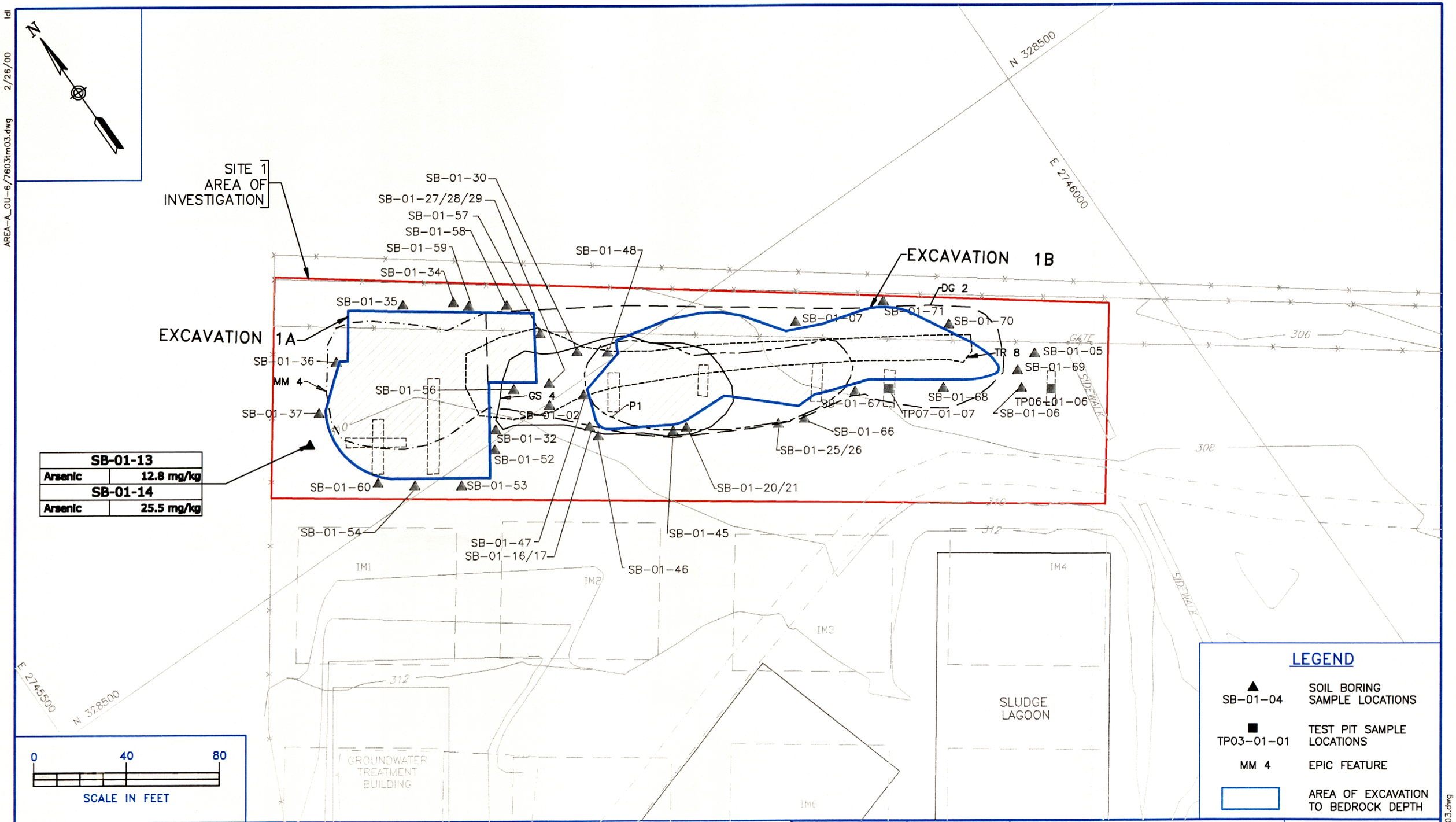

No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
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DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SCREENING CRITERIA EXCEEDANCES
AREA A – SITE 1
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Tea DATE 4/23/00
DRAWING NO. FIGURE 4-10
REV. 1

AREA-A_OU-6/7603tm03.dwg 2/26/00 ldl

AREA-A_OU-6/7603tm03.dwg

sample SB-01-14 was collected from a depth of 5 to 6 feet bgs. The soil boring log notes that refusal was encountered at 8 feet. No other notes or unusual observations appear. None of the compounds targeted for the removal action (TCE, antimony, cadmium, and chromium) were detected at levels above the screening criteria.

4.3 SITE 2

The confirmation borings (see Figure 4-1) drilled during the Phase I RI detected a variety of waste materials, including fill material, cinders, glass fragments, ceramic pieces, bricks and brick fragment, wood, and metal fragments. This waste may represent the regraded remains of material from Site 1, although no distinct scorched soil horizon was encountered. Waste found in the area believed to encompass Site 2 did not yield any evidence of wastewater sludges reported to be present. The thickness of surficial and subsurface fill material at Site 2 averaged between 4 and 5 feet. The average thickness of waste containing material was between 5 and 6 feet.

During Phase III, a total of 71 borings and four test pits were drilled or excavated in the vicinity of Site 2 (Figure 2-9). Boring logs for Site 2 soil borings are found in Appendix D. Test pit logs are contained in Appendix E. Twenty-six borings contained non-native materials, and the remaining borings encountered clean fill or native soil. The average thickness of waste material at Site 2 was between 4 and 6 feet from the ground surface. In one boring (SB-02-15), waste was present from the ground surface to bedrock at a depth of 12 feet. The average thickness of clean fill or native soils ranged from 4 to 6 feet as well.

Test pits and soil borings were advanced in the vicinity of EPIC feature TR2. Test pit nos. TP-01, TP-02, and TP-03 were excavated in an east-west direction along the center of the suspected trench. The trench appeared to be located in two of these test pits. A concrete stormwater drain pit was encountered at 4 feet during the excavation of test pit TP-01. Concrete construction debris, at a depth of 4 to 6 feet, was encountered in test pit TP-02. No waste materials were found during the excavation of test pit TP-03, which was located between TP-01 and TP-02.

Soil borings were located along the northern and eastern boundaries of TR2 and an area of mounded material (MM3) which appeared in a 1965 aerial photo. Three of these borings detected waste materials, including ash, charred debris, scrap metal, concrete fragments, and glass pieces. The depths of these materials ranged from 2.5 to 7 feet. HNu readings at the borings varied between non-detect and 1,200 ppm. The wastes found in the test pits and borings at Site 2 were consistent with the description of materials reportedly disposed in TR2.

Four borings were located within and near EPIC feature TR1. All borings encountered fill material (e.g., rocks, gravel, sand) from the ground surface to 2 feet and clean fill or native soil to 6.5 feet. The presence of waste materials within TR1 was not noted, and HNu readings above background were not recorded. Based on these borings and facility drawings, it appears that TR1 may have been excavated to install a storm sewer pipe in this general area.

Six soil borings were located within and near EPIC feature DG3. Three of the borings were based on soil gas anomalies detected during the Phase III RI soil gas survey. The remaining borings were located according to EPIC photographs. The three borings selected to further investigate soil gas anomalies were within the eastern portion of DG3. Elevated HNu readings were recorded in all three of these borings, ranging from 6 ppm at a depth of 1.5 feet to 1,200 ppm at 5 feet. Waste materials encountered in these borings included glass fragments. The three remaining borings were drilled near the northern and southern boundaries of DG3. At depths between 3 and 6 feet, these borings revealed a band of fill material consisting of glass, ceramic pieces, brick, charred wood, and an unknown chalky, powdery material. One elevated HNu reading was recorded in one of these borings.

In the vicinity of EPIC feature D1, 33 borings were advanced and one test pit was excavated. The locations of the borings and test pits were based on previous investigations, soil gas and EM anomalies, and EPIC photographs. The borings ranged between 5 and 12 feet in depth, with an average depth of 7 feet. Waste materials were encountered to a depth of 12 feet but averaged 3 feet. Clean fill and native soils were encountered between 3 and 5 feet.

Four borings, SB-02-17, SB-02-36, SB-02-44, and SB-02-45, were located along the approximate eastern boundary of D1. Waste materials were noted in each boring. Wastes ranged in depth between 4 and 9 feet and included materials such as slag, ash, cinders, coals, brick fragments, glass, and asphalt pieces. Boring SB-17 encountered clean fill to 6.5 feet until glass fragments were noted. No HNu readings above background were recorded.

Fourteen borings were drilled along the approximate northern boundary of D1. These borings ranged from 5 to 10 feet in depth, with clean fill or native soil present between 2 and 7 feet. Waste materials, including glass, brick, ash, slag, coal, cinders, asphalt, and a light blue to white soft solid material, were found in nine borings at depths between 5 and 7 feet. Vapor readings above background were not recorded in any of these borings.

Three borings were drilled along the suspected western boundary of D1. These borings ranged from 2.5 to 5 feet in depth. Clean fill or native soils were found in these borings. No waste materials or HNu readings were noted.

Five borings were advanced near the southern boundary of D1. These borings ranged between 5 and 12 feet in depth. Clean fill and native soils were found between 3 and 12 feet below the ground surface. Non-native materials (e.g., slag, ash, coal, cinders, brick fragments) were noted in borings SB-02-38 and SB-02-39 between 2 and 3 feet. HNu readings above background were detected in all five borings, ranging from 0.4 ppm in boring SB-02-14 to 15 ppm in SB-02-13.

The remaining borings within Site 2 were located throughout this general area. These borings ranged between 5 and 12 feet in depth, with clean fill or native soils ranging from 2 to 4 feet bgs. Non-native materials were noted in four borings (SB-02-15, SB-02-16, SB-02-21, and SB-02-43) that ranged in depth between 4 and 9 feet. Encountered wastes included coal, cinders, charred materials, ceramic pieces, glass, and black rock pieces. One HNu reading of 10 to 15 ppm was noted in boring SB-02-42; no other elevated readings were recorded.

Test Pit TP-08, excavated between the fuel storage area and EPIC feature D1, was located in an area of elevated soil gas readings (i.e., carbon tetrachloride at 150 ug/l). The test pit was 22 feet long and 3.5 feet deep. At 3 feet, a layer of gray clay with a vapor reading of 45 ppm was measured. Strong petroleum odors were also noted. The clay layer disappeared at 5.5 feet, where red brown silty clay was observed. Broken glass, metal, wires, concrete pieces, brick, cables, and steel rods were found.

VOCs were detected from the trench excavated for the groundwater transfer piping between the fuel farm and EPIC feature D1. Samples from the excavated trench were treated as soil borings for the purposes of this report. Borings SB-02-52 and SB-02-69 were located along the route of the excavation. Apparent waste materials were encountered between 3 and 10 feet bgs. These materials included cinders, glass, brick fragments, and other debris. VOC concentrations at this general location ranged up to 300 ppm. The types and thicknesses of material found in the Phase III RI borings conducted at Site 2 are included in Appendix E of the Phase III Draft RI Report (B&R Environmental, 1996a).

4.3.1 Site 2 Geophysical Survey Results

4.3.1.1 Phase III EM Survey

The Phase III EM survey in the vicinity of Site 2 showed one strong anomaly that was completely unrelated to buried utilities or cultural features. This anomaly was characterized by terrain conductivity and inphase readings that were much higher than the surrounding "background" readings. The anomaly was located beneath the patrol or entrance road southeast of the guardhouse and northwest of Site 3 (Figures 4-2 and 4-3). The terrain conductivity was very high, with a maximum value of 160 millimhos

per meter (mmhos). The inphase data indicated that buried metallic debris is a possible component of the fill material in and around their anomaly. This anomaly was located near, but not coincident with, aerial photo features TR2 and MM1 from the EPIC analysis.

Elevated conductivity values (both terrain conductivity and inphase readings) were recorded along the northeastern edge of the Site 2 area from near Site 3 to a point east of the former field office trailers (Figures 4-2 and 4-3). The most pronounced area of anomalous high-conductivity values was inside the base perimeter fence, directly east of the former trailers. Significant sources of cultural interference were also present throughout much of this area during geophysical data acquisition. These sources include metal fences, gates, and a guardhouse, steel monitoring well casings, light standards and their underground electric service lines, underground reinforced concrete pipe stormwater drains, a large steel trash dumpster, a parked front-end loader, and an aluminum staircase from one of trailers. It is suspected that the area of higher conductivity along the northeastern edge of the Site 2 area may represent an area of fill material possibly containing some buried metallic debris. However, the number and extent of cultural sources of interference in this area make interpretation of the EM data inconclusive.

Appendix B contains detailed information on the Phase III geophysical survey.

4.3.1.2 Supplemental Magnetic and EM Survey Results

As noted in Section 4.2.1.2, supplemental EM and magnetic surveys were conducted over portions of Area A, including Site 2 during the removal action. The surveys delineated three anomalous zones within the vicinity of Site 2. Anomalous Zone 2 was located on the northwestern edge of removal action Excavation 2A (see Figure 4-4). A portion of the anomalous zone was outside the excavation, and the other half was within the excavation. Wires and rusty cables were observed protruding from the wall of the excavation during the geophysical surveys. The anomalous zone was most likely related to the wires and cables that were visually observed by the survey team.

Anomalous Zone 3 was located primarily within Excavation 2A and was detected by both the EM and magnetic instruments. Visual observations indicated that the excavation area contained considerable metallic debris, primarily pieces of rusty metal. The EM data suggested that the debris was contained inside the fenced area north of Excavation 2A. The extreme eastern portion of Zone 3 extended into a thickly wooded area. It was not possible to obtain accurate data in this area adjacent to the fencing.

Anomalous Zone 4 was located south of the eastern edge of Excavation 2A and north of Excavation 2C. The anomalous area was likely located beneath the gravel roadway.

Seven test pits were excavated in Site 2 in October 1999 as a follow-up to the geophysical surveys. A detailed report on the test pit methodology and results are outlined in the November 1999, Results from Area A Supplemental Subsurface Soil Investigations letter report (TtNUS, 1999e). Test pit locations are shown on Figure 2-9. No visible evidence of waste was observed in test pits TP-9, TP-12, TP-13, and TP-15. Visible evidence of waste was observed in test pits TP-10, TP-11, and TP-14. As reported, debris in all three test pits consisted of fragments of glass, wood, metal, ceramic, plastic, wire, and pockets of a blue-green crystalline material. Analytical results from samples collected from each of the test pits are included in the database for Site 2 subsurface soils contained in Appendix A.

4.3.2 Site 2 Soil Gas Survey Results

The most recent soil gas survey in Site 2 was conducted as part of the Phase III RI. No additional surveys were conducted subsequent to that work. As outlined in the Phase III RI Report (B&R Environmental, 1996a), the significant soil gas results (Figures 4-5 through 4-7) for this general area are as follows:

- Elevated VOCs and BTEX compounds were detected in several soil gas samples near and within Site 2. Frequently detected chemicals included PCE, TCE, CCl_4, 1,1,1-TCA, and cis-1,2-DCE.

- An area of consistently elevated VOCs within Site 2 exists north of the fuel storage area and in the vicinity of several temporary trailers. Frequently detected chemicals included PCE, TCE, CCl_4, and 1,1-TCA. The highest PCE concentration in soil gas samples was 37 ug/l; for TCE, it was 34 ug/l; for CCl_4, it was 150 ug/l, and for 1,1,1-TCA, it was 3 ug/l. This area does not directly correspond to any EM anomaly or any EPIC feature. The area is about 250 by 250 feet in size.

- The highest BTEX levels were just west of the existing asphalt access road and near MM1 and MM2 in front of the guardhouse. Benzene was detected in soil gas samples at 500 ug/l near the access road and at 1,500 ug/l between MM1 and MM2.

- CCl_4, 1,1,1-TCA, PCE, and TCE were generally not found in soil gas samples collected in the eastern half of the Site 2 area (i.e., within 350 feet of the guardhouse).

- Soil gas samples taken from within the estimated boundary of Site 2 (as delineated before Phase III RI work) had very few positive detections of VOCs.

4.3.3 Site 2 Surface Soil Results

4.3.3.1 Pre-Removal Sample Results

Tables 4-7 and 4-8 provide the occurrence and distribution of inorganic and organic compounds in background and site-related surface soil samples for Site 2 collected as part of the RI activities. As part of the 1998 removal action, certain surface and subsurface soils were excavated from Site 2 and disposed off site. Figure 4-11 details the Site 2 excavation areas, that consisted of Excavations 2A, 2B, and 2C. The excavations were targeted to remove surface soils containing lead and antimony present at levels unacceptable to current and future use scenarios. As reported in the May 1999 Post Removal Summary Report Area A, Sites 1, 2, and 3 (TtNUS, 1999a), Excavation 2A consisted of the removal of about the top 2 to 3 feet of soil over the entire area and a deeper subsurface component (refer to Section 4.3.4.2). Excavation 2A covered an area of approximately 170 feet by 60 feet. Three sampling events were conducted during and after the excavation to direct ana verify the effectiveness the removal action.

4.3.3.2 Post-Removal Sample Results

Table 4-9 presents the occurrence and distribution of organics and inorganics in Site 2 surface soil samples remaining in place after the 1998 removal action. The analytical data were compared to federal and state soil screening criteria, as detailed in Appendix A. Figure 4-12 shows the locations of existing surface soil samples where concentrations exceeded soil screening criteria and the maximum background concentration, as noted in Table 4-9. Samples from 10 locations had concentrations that exceeded the criteria and maximum background concentrations. The compound most frequently exceeded was benzo(a)pyrene (exceeded in 10 samples). No other screening criteria for organic compounds were exceeded. Lead was the only inorganic compound above the screening criteria, in sample SS-02-22. The lead concentration detected in sample SS-02-22 (994J mg/kg) was below the removal action clean-up goal as determined by the Navy, EPA, and the BRAC Clean-up Team (BCT) (TtNUS, 1999).

4.3.4 Site 2 Subsurface Soil Results

4.3.4.1 Pre-Removal Sample Results

During the 1998 removal action, subsurface soils were excavated from a portion of Excavations 2A and 2B. Excavation depths were 2 to 4 feet below grade. Tables 4-10 and 4-11 present the occurrence and distribution of inorganic and organic compounds in background and Site 2 subsurface samples collected

TABL

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SITE 2 SURFACE SOIL

WARMINSTER, PENNSYLVANIA

(mg/kg)

	BACKGROUND			SITE-RELATED		
SUBSTANCE	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION*	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	REPRESENTATIVE CONCENTRATION
ALUMINUM	31 / 31	4780 - 18100	15282	16 / 16	9710 - 19800	16225
ANTIMONY	1 / 22	13.6	4.65	4 / 14	7.9 - 842	171.55
ARSENIC	27 / 31	0.28 - 12.1	10.50	16 / 16	3.1 - 22.8	9.45
BARIUM	27 / 29	34.1 - 225	74.12	16 / 16	47 - 589	222.30
BERYLLIUM	27 / 31	0.31 - 1.7	0.90	16 / 16	0.61 - 1.4	1.12
CADMIUM	0 / 31	-	-	5 / 14	0.76 - 28.4	9.76
CALCIUM	25 / 29	240 - 1910	773	16 / 16	1050 - 38800	15448
CHROMIUM	31 / 31	7.9 - 35.3	21.59	16 / 16	19.1 - 184	80.09
COBALT	27 / 30	1.6 - 22.1	10.32	16 / 16	8.3 - 14.5	12.35
COPPER	29 / 31	3.6 - 30.6	13.56	16 / 16	7.7 - 3070	756.71
CYANIDE	0 / 21	-	-	1 / 16	1.1	0.42
IRON	31 / 31	6980 - 410500	54527	16 / 16	16000 - 66700	34621
LEAD	31 / 31	1.6 - 96.5	16.69	16 / 16	9.4 - 80800	14026
MAGNESIUM	27 / 31	518 - 4960	2472	16 / 16	1810 - 16300	7667
MANGANESE	31 / 31	30.9 - 2010	527.88	16 / 16	350.5 - 1420.5	933.91
MERCURY	1 / 28	0.37	0.06	4 / 4	0.33 - 1.5	1.50
NICKEL	20 / 27	4.1 - 21.7	14.40	4 / 4	17.7 - 52.1	52.10
POTASSIUM	27 / 29	89.1 - 3050	886	16 / 16	527 - 2570	1437
SILVER	0 / 17	-	-	6 / 10	1.2 - 43.9	16.17
SODIUM	5 / 20	55.2 - 86.7	86.7	3 / 3	285 - 392	392
THALLIUM	3 / 31	0.37 - 0.42	0.42	1 / 16	0.81	0.37
VANADIUM	31 / 31	15.4 - 45	33.01	16 / 16	20.3 - 86.75	44.96
ZINC	27 / 29	9 - 60	31.34	16 / 16	25.2 - 12400	2355

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

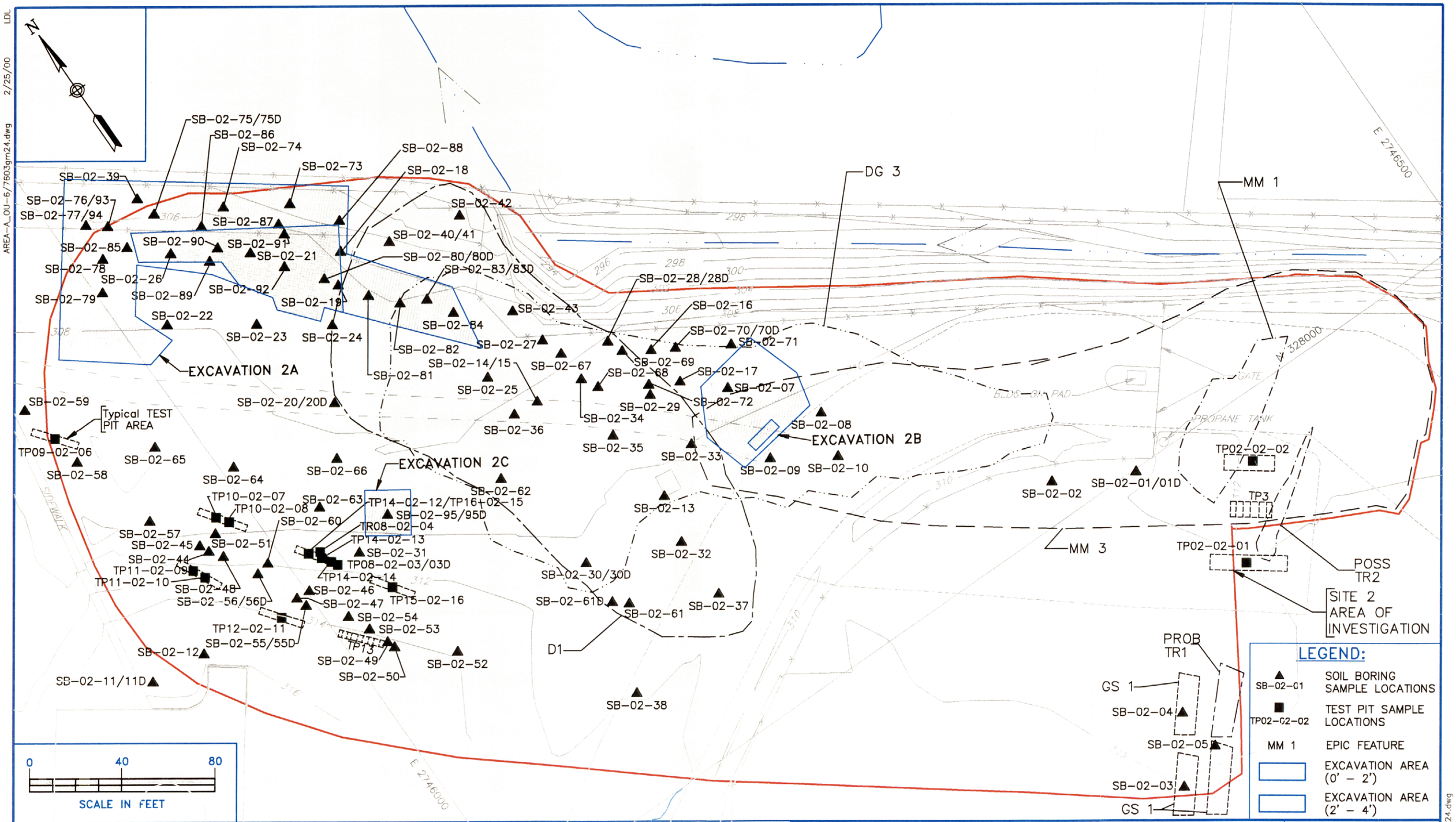
** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4-8
OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 2 SURFACE SOIL
WARMINSTER, PENNSYLVANIA
(ug/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION*	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	REPRESENTATIVE CONCENTRATION
4,4'-DDE	1 / 21	820	108.13	2 / 16	3.9 - 7.9	3.04
4,4'-DDT	1 / 21	1440	188.58	8 / 16	4.2 - 51	15.98
ALPHA-CHLORDANE	0 / 21	-	-	4 / 16	4.3 - 160	28.90
AROCLOR-1254	1 / 21	51	51.00	9 / 16	11 - 3700	670.53
AROCLOR-1260	0 / 21	-	-	1 / 16	100	32.42
DIELDRIN	0 / 21	-	-	2 / 16	4 - 32	7.16
ENDOSULFAN I	0 / 21	-	-	1 / 16	7	1.98
ENDOSULFAN II	0 / 21	-	-	1 / 16	4.7	2.33
ENDRIN	0 / 21	-	-	8 / 16	5.75 - 370	68.81
GAMMA-BHC	0 / 21	-	-	7 / 16	2.25 - 5.9	2.81
GAMMA-CHLORDANE	0 / 21	-	-	2 / 16	8.7 - 11	3.40
2-METHYLNAPHTHALENE	0 / 11	-	-	1 / 16	46	46
ACENAPHTHENE	0 / 11	-	-	8 / 16	41 - 180	180
ACENAPHTHYLENE	0 / 11	-	-	6 / 16	44 - 120	120
ANTHRACENE	0 / 11	-	-	10 / 16	75 - 545	320.55
BENZ(A)ANTHRACENE	0 / 11	-	-	10 / 16	310 - 2850	2416
BENZO(A)PYRENE	0 / 11	-	-	10 / 16	300 - 3150	1266
BENZO(B)FLUORANTHENE	1 / 11	58	58	10 / 16	400 - 5000	2088
BENZO(G,H,I)PERYLENE	0 / 11	-	-	10 / 16	200 - 1500	982
BENZO(K)FLUORANTHENE	1 / 11	46	46	9 / 16	110 - 1800	605.17
BIS(2-ETHYLHEXYL)PHTHALATE	1 / 11	50	50	3 / 4	940 - 1600	1800
CARBAZOLE	0 / 11	-	-	8 / 16	100 - 485	254.61
CHRYSENE	1 / 11	51	51	10 / 16	280 - 3150	1261
DI-N-BUTYL PHTHALATE	0 / 11	-	-	2 / 14	43 - 61	61
DIBENZ(A,H)ANTHRACENE	0 / 11	-	-	6 / 16	37 - 470	220.25
DIBENZOFURAN	0 / 11	-	-	6 / 16	41 - 98	98
FLUORANTHENE	1 / 11	92	92	11 / 16	43 - 5900	2323
FLUORENE	0 / 11	0 - 0	-	9 / 16	40 - 225	216.59
INDENO(1,2,3-CD)PYRENE	0 / 11	0 - 0	-	10 / 16	180 - 1600	977.86
NAPHTHALENE	0 / 11	0 - 0	-	1 / 16	52	52
PYRENE	1 / 11	100	100	11 / 16	40 - 4150	2035
TETRACHLOROETHENE	0 / 20	0 - 0	-	1 / 16	10	6.29
TOLUENE	3 / 20	2	2	1 / 16	2	2

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SOIL BORING LOCATIONS ADDED.	LDL			

DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

SOIL EXCAVATION AREAS

AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMNSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY RPO DATE 4/23/00
DRAWING NO. FIGURE 4-11
REV. 1

AREA-A_OU-6/7603gm24.dwg
LDL 2/25/00

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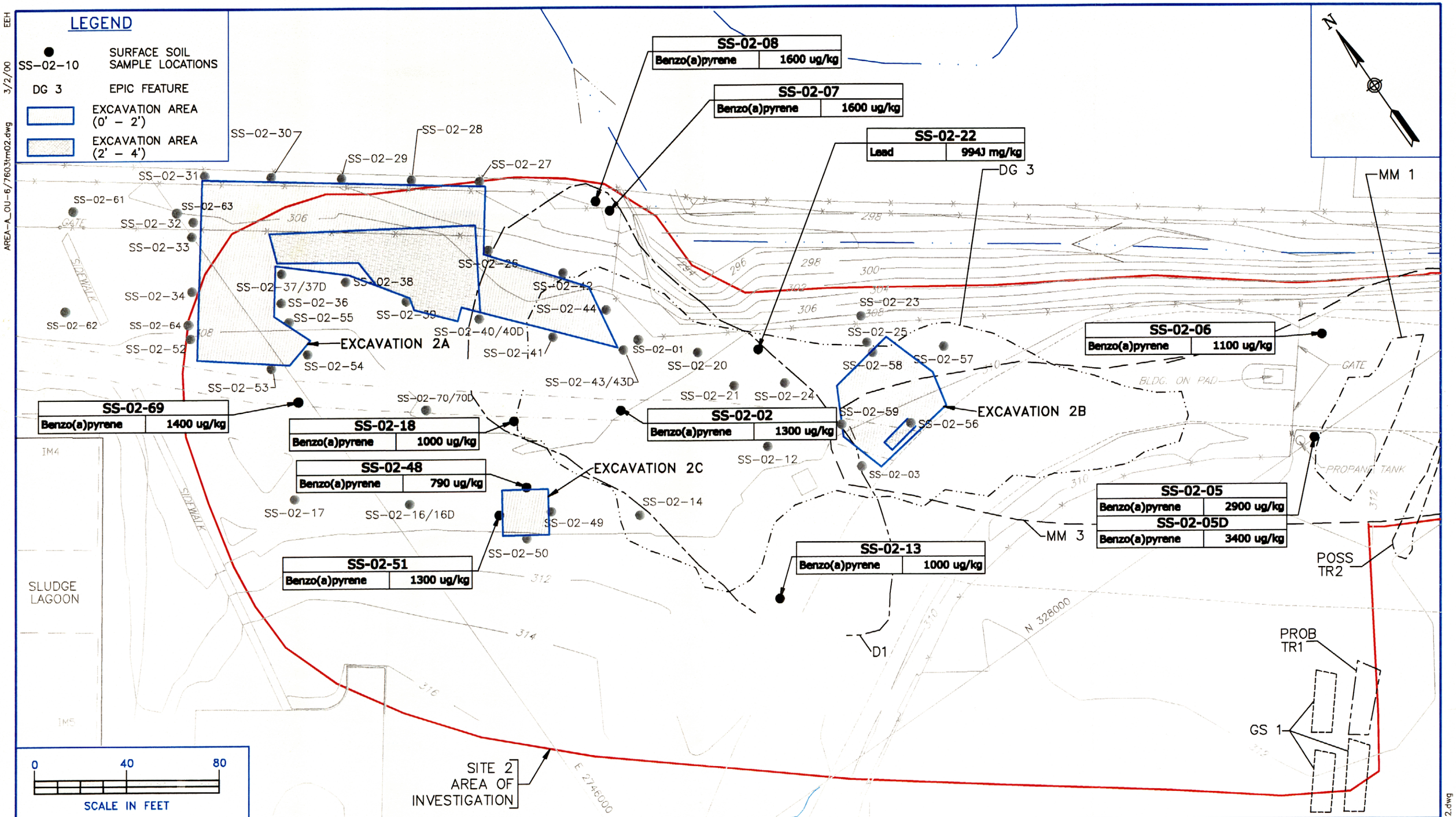
OCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA
PAGE 1 OF 2

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	20/20	142 - 19800	12,738	SS-02-63	19,800
ANTIMONY	1/29	13.6	BG-16	4.11	24/46	0.19 - 10.8	2.18	SS-02-42	3.81
ARSENIC	25/29	0.28 - 12.1	BG-11	11.7	20/20	0.88 - 13.1	5.40	SS-02-03	7.10
BARIUM	25/29	34.1 - 225	BG-28	87.1	20/20	4.4 - 452	119	SS-02-07-MAX	224
BERYLLIUM	25/29	0.31 - 1.7	BG-23-MAX	0.88	19/20	0.63 - 1.4	0.94	SS-02-64, SS-02-16-MAX	1.06
CADMIUM	0/29				36/48	0.09 - 20.3	2.55	SS-02-26	7.7
CALCIUM	23/29	240 - 1910	BG-24	781	20/20	1050 - 215000	19,443	SS-02-56	42,064
CHROMIUM	29/29	7.9 - 35.3	BG-12	21.7	24/24	1.1 - 133	46.6	SS-02-05-MAX	87.6
COBALT	25/29	1.6 - 22.1	BG-23-MAX	10.4	20/20	0.74 - 14.5	11.0	SS-02-06	14.5
COPPER	27/29	3.6 - 30.6	BG-29	14.1	44/44	5.7 - 1410	114	SS-02-22	161
IRON	29/29	6980 - 410500	BG-04	35,030	20/20	2360 - 38000	22,818	SS-02-07-MAX	25,933
LEAD	29/29	1.6 - 96.5	BG-13	16.4	48/48	8 - 994	108	SS-02-22	152
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	20/20	1900 - 135000	12,346	SS-02-56	16,429
MANGANESE	29/29	30.9 - 2010	BG-28	604	20/20	169 - 2080	711	SS-02-05-MAX	903
MERCURY	1/29	0.37	BG-23-MAX	0.05	8/20	0.18 - 1.1	0.25	SS-02-14	0.57
NICKEL	18/29	4.1 - 21.7	BG-23-MAX	11.1	11/20	4.9 - 47	15.3	SS-02-07-MAX	20.7
POTASSIUM	25/29	89.1 - 3050	BG-24	997	19/20	684 - 2590	1,403	SS-02-18	1,679
SELENIUM	0/29				3/18	0.89 - 1.6	0.47	SS-02-07-MAX	0.61
SILVER	0/29				25/43	0.14 - 58.4	3.83	SS-02-07-MAX	23.3
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	12/20	84.8 - 1870	273	SS-02-14	500
THALLIUM	3/29	0.37 - 0.42	BG-23-MAX	0.42	6/24	0.81 - 1.4	0.51	SS-02-07-MAX	0.68
VANADIUM	29/29	15.4 - 45	BG-12	32.2	20/20	24.1 - 119	39.1	SS-02-05-MAX	46.0
ZINC	25/29	9 - 60	BG-13	30	44/44	23 - 4800	319	SS-02-22	428
2-METHYLNAPHTHALENE	0/11				2/20	46 - 21000	1,264	SS-02-56	1,033
ACENAPHTHENE	0/11				4/20	43 - 180	1,033	SS-02-06	180
ACENAPHTHYLENE	0/11				6/20	44 - 440	1,027	SS-02-07-MAX	440
ANTHRACENE	0/11				12/20	51 - 640	1,037	SS-02-05-MAX	640
BENZO(A)ANTHRACENE	0/11				16/23	190 - 3300	1,413	SS-02-05-MAX	2,198
BENZO(A)PYRENE	0/11				17/24	47 - 3400	1,433	SS-02-05-MAX	2,590
BENZO(B)FLUORANTHENE	1/11	58	BG-13	58	14/20	300 - 5300	2,015	SS-02-05-MAX	4,841
BENZO(G,H,I)PERYLENE	0/11				23/38	55 - 4400	1,129	SS-02-39	1,522
BENZO(K)FLUORANTHENE	1/11	46	BG-13	46	14/20	110 - 1800	1,314	SS-02-05-MAX	1,756
BIS(2-ETHYLHEXYL)PHTHALATE	1/11	50	BG-16	50	2/20	1000 - 1800	1,115	SS-02-70-MAX	1,800
CARBAZOLE	0/11				9/20	48 - 560	1,000	SS-02-05-MAX	560
CHRYSENE	1/11	51	BG-13	51	14/20	260 - 3300	1,633	SS-02-05-MAX	3,009
DI-N-BUTYL PHTHALATE	0/11				2/20	43 - 61	1,033	SS-02-02	61.0
DIBENZO(A,H)ANTHRACENE	0/11				7/20	37 - 470	994	SS-02-05-MAX	470
DIBENZOFURAN	0/11				4/20	41 - 73	1,022	SS-02-02, SS-02-06	73.0
FLUORANTHENE	1/11	92	BG-13	92	14/20	390 - 6200	2,141	SS-02-05-MAX	5,211
FLUORENE	0/11				6/20	58 - 250	997	SS-02-05-MAX	250
INDENO(1,2,3-CD)PYRENE	0/11				31/41	37 - 5000	1,151	SS-02-39	1,717
NAPHTHALENE	0/11				1/20	52	1,039	SS-02-06	52.0
PHENANTHRENE	1/11	51	BG-13	51	14/20	120 - 3700	1,511	SS-02-05-MAX	2,742
PYRENE	1/11	100	BG-13	100	14/20	290 - 4600	1,925	SS-02-05-MAX	4,297

TABLE 4-9
OCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
TOLUENE	3/21	2	BG-17	2	1/12	2	6.08	SS-02-03	2.00
4,4'-DDD	1/23	16	BG-12	3	1/12	19	3.28	SS-02-56	4.57
4,4'-DDE	1/23	820	BG-12	15.3	1/12	8	3.08	SS-02-01	4.54
4,4'-DDT	1/23	1440	BG-12	21.5	4/12	4.2 - 23	5.32	SS-02-01	10.3
ALPHA-CHLORDANE	0/23				2/12	4.6 - 160	15.3	SS-02-69	50.4
AROCLOR-1254	1/23	51	BG-13	41.3	12/20	11 - 3700	284	SS-02-69	596
AROCLOR-1260	0/23				1/20	110	27.7	SS-02-08	33.5
DIELDRIN	0/23				1/12	32	5.08	SS-02-69	9.05
ENDRIN	0/23				4/12	5.8 - 370	35.4	SS-02-69	123
GAMMA-BHC (LINDANE)	0/23				5/12	2.3 - 5	2.65	SS-02-06	4.84
GAMMA-CHLORDANE	0/23				1/12	11	2.58	SS-02-69	4.98

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.
Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SURFACE SOIL SAMPLE SS-02-59 LOCATION UPDATED.	LDL			

DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SURFACE SOIL CONCENTRATIONS
SCREENING CRITERIA EXCEEDANCES
AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY HPa DATE 4/25/00
DRAWING NO. FIGURE 4-12
REV. 1

EEH 3/2/00 AREA-A_OU-6/7603tm02.dwg

442B204

TAB. -10

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SITE 2 SUBSURFACE SOIL

NAWC WARMINSTER, PENNSYLVANIA

(mg/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
ALUMINUM	31 / 31	4780 - 18100	15282	74 / 74	5210 - 137000	14943
ANTIMONY	1 / 22	13.6 - 13.6	4.65	15 / 47	2.2 - 317	28.41
ARSENIC	27 / 31	0.28 - 12.1	10.50	67 / 68	0.85 - 19.6	6.08
BARIUM	27 / 29	34.1 - 225	74.12	74 / 74	21.6 - 790	165.60
BERYLLIUM	27 / 31	0.31 - 1.7	0.90	61 / 62	0.25 - 8.2	1.05
CADMIUM	0 / 31	-	-	24 / 60	0.49 - 293	9.23
CALCIUM	25 / 29	240 - 1910	773	73 / 73	387 - 74000	11174
CHROMIUM	31 / 31	7.9 - 35.3	21.59	74 / 74	4 - 14100	169.88
COBALT	27 / 30	1.6 - 22.1	10.32	73 / 73	3.5 - 43.3	11.43
COPPER	29 / 31	3.6 - 30.6	13.56	73 / 73	4.6 - 6800	210
CYANIDE	0 / 21	-	-	6 / 57	0.6 - 20.4	1.34
HEXAVALENT CHROMIUM	0 / 9	-	-	7 / 17	0.95 - 15.7	3.36
IRON	31 / 31	6980 - 410500	54527	74 / 74	4000 - 103000	24496
LEAD	31 / 31	1.6 - 96.5	16.69	66 / 66	1.5 - 4570	291.14
MAGNESIUM	27 / 31	518 - 4960	2472	73 / 73	680 - 29900	4213
MANGANESE	31 / 31	30.9 - 2010	527.88	74 / 74	127 - 1760	614.04
MERCURY	1 / 28	0.37	0.06	31 / 74	0.06 - 1.3	0.21
NICKEL	20 / 27	4.1 - 21.7	14.40	64 / 64	3.1 - 143	25.44
POTASSIUM	27 / 29	89.1 - 3050	886	68 / 68	110 - 2690	1013.81
SELENIUM	0 / 20	-	-	4 / 72	0.62 - 3	0.47
SILVER	0 / 17	-	-	25 / 74	0.52 - 168	11.82
SODIUM	5 / 20	55.2 - 86.7	86.7	41 / 41	45 - 2910	347.59
THALLIUM	3 / 31	0.37 - 0.42	0.42	1 / 67	1.9	0.48
VANADIUM	31 / 31	15.4 - 45	33.01	73 / 74	5.7 - 586	44.95
ZINC	27 / 29	9 - 60	31.34	74 / 74	5.2 - 24900	673.74

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4-11 (PAGE 1 OF 2)
OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 2 SUBSURFACE SOIL
NAWC WARMINSTER, PENNSYLVANIA
(ug/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
OCDD	0 / 3	-	-	4 / 5	0.25 - 0.68	0.68
OCDF	0 / 3	-	-	1 / 5	0.25	0.25
4,4'-DDD	1 / 21	16	3.81	9 / 44	2.1 - 91	9.62
4,4'-DDE	1 / 21	820	108.13	4 / 44	4.8 - 82	7.91
4,4'-DDT	1 / 21	1440	188.58	9 / 44	1.8 - 150	14.56
ALDRIN	0 / 21	-	-	2 / 44	3.6 - 180	12.19
ALPHA-CHLORDANE	0 / 21	-	-	1 / 44	5.9	1.83
AROCLOR-1248	0 / 21	-	-	1 / 44	110	35.78
AROCLOR-1254	1 / 21	51	51	8 / 44	11 - 5900	408.44
AROCLOR-1260	0 / 21	-	-	8 / 44	9 - 1600	142.47
DELTA-BHC	0 / 21	-	-	1 / 44	2.1	1.71
DIELDRIN	0 / 21	-	-	2 / 44	4.3 - 5.8	3.46
ENDOSULFAN II	0 / 21	-	-	3 / 43	1.9 - 8.5	2.69
ENDRIN	0 / 21	-	-	8 / 44	2.1 - 24	5.66
ENDRIN KETONE	0 / 21	-	-	4 / 44	1.6 - 5.5	3.37
GAMMA-BHC	0 / 21	-	-	1 / 44	2.5	1.72
GAMMA-CHLORDANE	0 / 21	-	-	3 / 44	2.3 - 14	2
HEPTACHLOR EPOXIDE	0 / 21	-	-	1 / 44	3.5	1.74
1,4-DICHLOROBENZENE	1 / 11	43	43	1 / 38	68	68
2-METHYLNAPHTHALENE	0 / 11	-	-	5 / 38	110 - 9800	1337
3,3'-DICHLOROBENZIDINE	0 / 11	-	-	1 / 38	400	400
4-METHYL-2-PENTANONE	0 / 20	-	-	1 / 59	110	110
ACENAPHTHENE	0 / 11	-	-	7 / 38	54 - 1400	675.81
ANTHRACENE	0 / 11	-	-	12 / 38	63 - 2200	710.89
BENZ(A)ANTHRACENE	0 / 11	-	-	25 / 38	49 - 5200	994.59
BENZO(A)PYRENE	0 / 11	-	-	24 / 38	44 - 5200	954.70
BENZO(B)FLUORANTHENE	1 / 11	58	58	25 / 38	51 - 5900	1088
BENZO(G,H,I)PERYLENE	0 / 11	-	-	21 / 38	51 - 3400	596.11
BENZO(K)FLUORANTHENE	1 / 11	46	46	23 / 38	23 - 2700	583.33
BIS(2-ETHYLHEXYL)PHTHALATE	1 / 11	50	50	6 / 27	46 - 2200	971.40

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4- GE 2 OF 2)

OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 2 SUBSURFACE SOIL

NAWC WARMINSTER, PENNSYLVANIA

(ug/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
BUTYL BENZYL PHTHALATE	0 / 11	-	-	4 / 38	53 - 110	110
CARBAZOLE	0 / 11	-	-	7 / 38	69 - 1300	680.74
CHRYSENE	1 / 11	51	51	25 / 38	43 - 5100	1000
DI-N-BUTYL PHTHALATE	0 / 11	-	-	7 / 36	46 - 4200	864.43
DIBENZ(A,H)ANTHRACENE	0 / 11	-	-	7 / 38	60 - 450	450
DIBENZOFURAN	0 / 11	-	-	5 / 38	88 - 880	657.35
DIETHYL PHTHALATE	0 / 11	-	-	2 / 38	48 - 67	67
FLUORANTHENE	1 / 11	92	92	25 / 38	80 - 13000	1825
FLUORENE	0 / 11	-	-	9 / 38	53 - 1400	651.38
INDENO(1,2,3-CD)PYRENE	0 / 11	-	-	20 / 38	29 - 3400	765.13
N-NITROSODIPHENYLAMINE	0 / 11	-	-	1 / 38	1000	650.81
NAPHTHALENE	0 / 11	-	-	6 / 38	51 - 1000	638.47
PENTACHLOROPHENOL	0 / 11	-	-	1 / 38	62	62
PYRENE	1 / 11	100	100	26 / 38	42 - 9800	1597
1,1-DICHLOROETHANE	0 / 20	-	-	1 / 59	16	16
1,2-DICHLOROETHENE (TOTAL)	0 / 20	-	-	5 / 59	2 - 60	60
2-BUTANONE	0 / 20	-	-	3 / 58	16 - 60	60
ACETONE	4 / 19	8 - 12	12	7 / 27	49 - 170	100.79
BENZENE	0 / 20	-	-	1 / 59	1	1
BROMOMETHANE	0 / 16	-	-	1 / 58	360	25.13
CARBON DISULFIDE	0 / 20	-	-	1 / 59	3	3
CHLOROFORM	0 / 20	-	-	1 / 59	1	1
CHLOROMETHANE	2 / 20	3	3	1 / 58	810 - 810	39.42
ETHYLBENZENE	0 / 20	-	-	3 / 59	3 - 13	13
METHYLENE CHLORIDE	0 / 13	-	-	4 / 17	1 - 23	8.24
TETRACHLOROETHENE	0 / 20	-	-	10 / 59	2 - 36	36
TOLUENE	3 / 20	2	2	6 / 57	2 - 150	28.56
TOTAL XYLENES	0 / 20	-	-	4 / 59	10 - 430	430
TRANS-1,3-DICHLOROPROPENE	0 / 20	-	-	1 / 59	97.75	97.75
TRICHLOROETHENE	0 / 20	-	-	8 / 59	2 - 12	12

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

as part of the RI scope of work. The areas of excavation are shown on Figure 4-11. In Excavation 2A, clean-up goals were established for lead and antimony, the compounds targeted by the removal action. The removal of subsurface soils from Excavation 2B was due to the presence of what appeared to be residual petroleum contamination (TtNUS, 1999a). Detailed information regarding the removal activities is found in the May 1999 report.

4.3.4.2 Post-Removal Sample Results

Table 4-12 presents the occurrence and distribution of organics and inorganics in Site 2 subsurface soil samples remaining after the 1998 removal action. Figure 4-13 details those existing soil samples where concentrations exceeded the screening criteria and maximum observed background concentrations. Compounds with exceedences were benzo(a)pyrene, arsenic, and lead. No other compounds were exceeded. The clean-up goal established for benzo(a)pyrene for Excavation Area 2C surface soil was 78,000 ug/kg (TtNUS, 1999a). All the benzo(a)pyrene exceedances were below the Excavation Area 2C goal. The clean-up goal for lead in subsurface soils in Excavation 2A was 1,750 mg/kg. Lead exceeded the screening criteria in five sample locations; however, three of these (SB-02-42, SB-02-69, and SB-02-93) were below the established clean-up goal. Samples SB-02-71 and SB-02-81 were the only locations that exceeded the Excavation 2A clean-up goal. A review of the boring log for SB-02-71 indicated that the depth of the sample was 12 feet bgs, which is at or near the normal water level. No clean-up goal was established for arsenic.

4.4 SITE 3

Seven confirmation borings were conducted at Site 3 during Phase I. Each of the borings encountered fill and/or waste material, which suggested that the entire area north of the entrance road and south of the unnamed tributary of Little Neshaminy Creek had been re-worked (Figure 4-1).

The confirmation borings revealed that the thickness of fill and waste material was between 6 and 10 feet. VOC vapor were encountered in borings up to 20 ppm. In addition, a gray, clay-like material containing organic vapors (at a steady 1 to 2 ppm concentration) was discovered in one boring (S3-1). Cinders, buried wood, metal, brick, and glass fragments, probably representing unburned portions of material disposed near EPIC feature DG1, were encountered in several borings from this general location.

Three test pits and 10 borings were excavated or drilled within Site 3 during the Phase III RI (see Figure 2-10). Information from previous investigations and EPIC photographs was used to select all subsurface locations. Test pits 1, 2, and 3 encountered clean fill to a depth of 3 feet bgs. Clean fill or native soils

T[illegible]12

OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 2 SUBSURFACE SOIL (POST-REMOVAL)

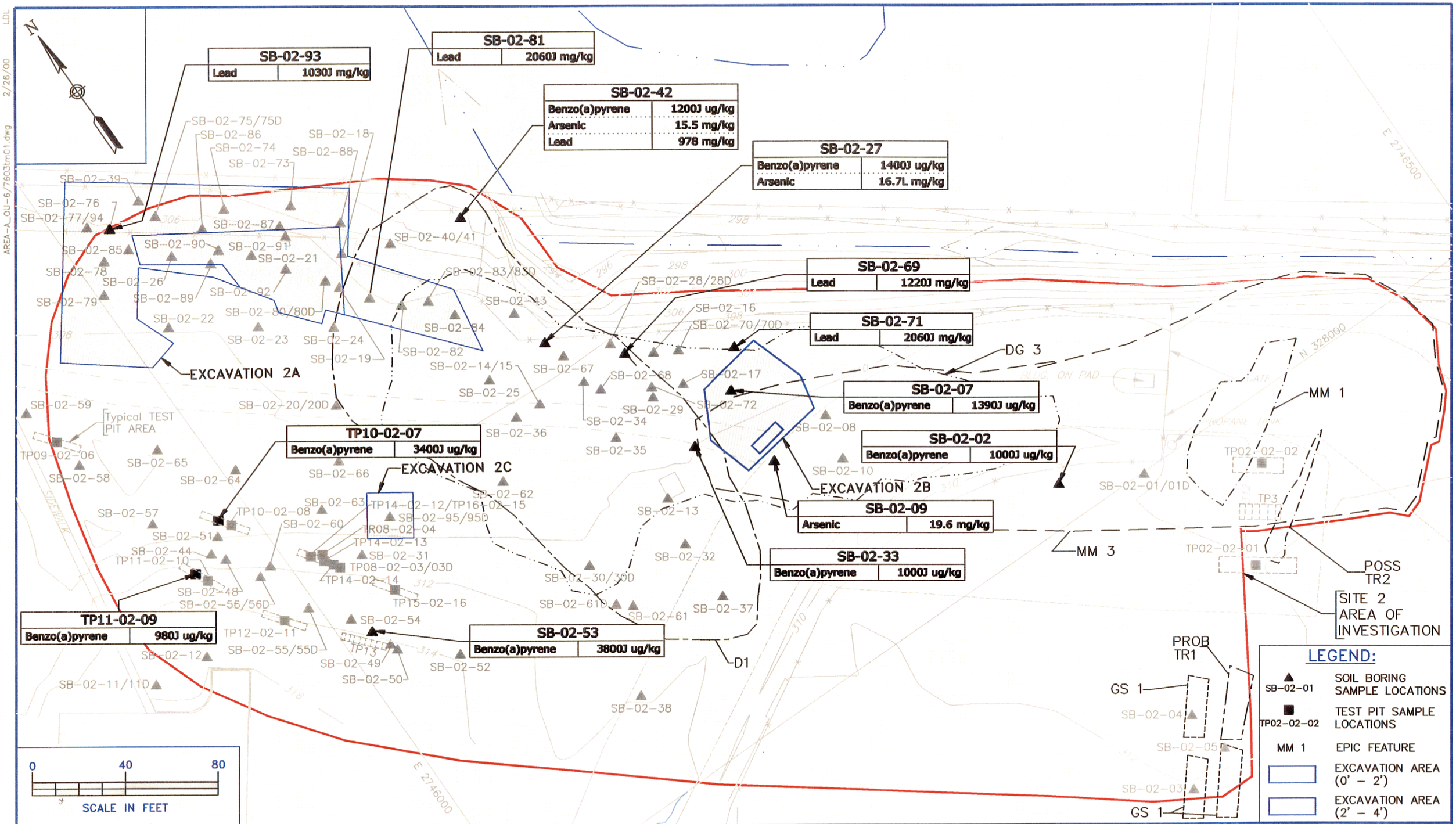
NAWC WARMINSTER, PENNSYLVANIA

	Background Data				Site Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	66/66	5210 - 133000	14,984	TP10-0207	16,637
ANTIMONY	1/29	13.6	BG-16	4.11	36/76	0.37 - 90.5	7.27	SB-02-16	11.47
ARSENIC	25/29	0.28 - 12.1	BG-11	11.7	60/66	0.85 - 19.6	4.72	SB-02-09	6.26
BARIUM	25/29	34.1 - 225	BG-28	87.1	66/66	21.6 - 719	116	SB-02-28-MAX	121
BERYLLIUM	25/29	0.31 - 1.7	BG-23-MAX	0.88	56/66	0.25 - 8.2	0.89	SB-02-42	0.92
CADMIUM	0/29				44/93	0.14 - 293	8.10	SB-02-27	7.70
CALCIUM	23/29	240 - 1910	BG-24	781	65/66	366 - 74000	7,316	SB-02-15	9,426
CHROMIUM	29/29	7.9 - 35.3	BG-12	21.7	66/66	4 - 3840	173	SB-02-16	95
COBALT	25/29	1.6 - 22.1	BG-23-MAX	10.4	65/66	3.5 - 24.8	10.11	SB-02-08	10.7
COPPER	27/29	3.6 - 30.6	BG-29	14.1	79/80	4.6 - 7980	467	SB-02-75-MAX	396
CYANIDE	0/20				4/46	0.93 - 20.4	1.26	SB-02-16	0.91
IRON	29/29	6980 - 410500	BG-04	35,030	66/66	4000 - 103000	22,989	SB-02-08	26,992
LEAD	29/29	1.6 - 96.5	BG-13	16.4	86/93	1.5 - 2060	155	SB-02-71	230
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	65/66	680 - 29900	3,461	SB-02-32	3,522
MANGANESE	29/29	30.9 - 2010	BG-28	604	66/66	127 - 1760	545	SB-02-28-MAX	583
MERCURY	1/29	0.37	BG-23-MAX	0.05	25/66	0.04 - 0.98	0.13	SB-02-17	0.14
NICKEL	18/29	4.1 - 21.7	BG-23-MAX	11.1	57/66	3.1 - 143	18.6	SB-02-42	18.7
POTASSIUM	25/29	89.1 - 3050	BG-24	997	60/66	110 - 2690	813	SB-02-37	948
SELENIUM	0/29				4/60	0.78 - 7.3	0.53	TP10-0207	0.54
SILVER	0/29				30/81	0.11 - 317	14.2	SB-02-70-MAX	12.4
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	33/66	45 - 2910	137	TP02-02-02	134
THALLIUM	3/29	0.37 - 0.42	BG-23-MAX	0.42	1/66	0.69	0.50	TP10-0207	0.51
VANADIUM	29/29	15.4 - 45	BG-12	32.2	66/66	5.7 - 586	38.3	SB-02-42	41.4
ZINC	25/29	9 - 60	BG-13	30	80/80	5.2 - 5640	453	SB-02-42	535
1,1-DICHLOROETHANE	0/21				1/53	16	36.3	SB-02-35	16.0
1,2-DICHLOROETHENE (TOTAL)	0/21				3/53	3 - 60	36.8	SB-02-12	22.0
2-BUTANONE	0/21				3/53	4.5 - 20	38.5	SB-02-02	24.0
2-HEXANONE	0/19				2/53	1 - 2	36.9	TP11-0209	2.00
4-METHYL-2-PENTANONE	0/21				4/53	0.9 - 110	38.8	SB-02-31	27.6
ACETONE	0/21				8/53	49 - 170	64.0	SB-02-10	109
BENZENE	0/21				3/53	1 - 8	36.2	TP10-0207	8.00
BROMOMETHANE	0/21				1/52	360	22.3	SB-02-09	17.1
CARBON DISULFIDE	0/19				2/53	2 - 10	36.2	TP14-0213	10.0
CHLOROETHANE	0/19				1/53	3	36.4	TP11-0209	3.00
CHLOROFORM	0/19				1/53	1	36.0	TP02-02-02	4.00
CHLOROMETHANE	0/21				1/53	810	27.9	SB-02-09	17.8
ETHYLBENZENE	0/21				3/53	3 - 13	35.3	SB-02-32	13.0
METHYLENE CHLORIDE	0/21				5/53	1 - 23	21.7	SB-02-32	15.8
TETRACHLOROETHENE	0/21				13/53	2 - 36	36.4	SB-02-11-MAX	23.0
TOLUENE	3/21	2	BG-17	2	6/53	2 - 150	38.1	SB-02-32	26.2
TRANS-1,3-DICHLOROPROPENE	0/21				1/53	97.75	37.9	SB-02-07	25.0
TRICHLOROETHENE	0/21				12/53	1 - 12	36.2	SB-02-19	12.0
1,4-DICHLOROBENZENE	1/11	43	BG-11	43	1/38	68	371	SB-02-07	68.0
3,3'-DICHLOROBENZIDINE	0/11				1/38	400	380	SB-02-07	400
ACENAPHTHENE	0/11				6/38	75 - 1400	408	SB-02-53	471
ANTHRACENE	0/11				10/38	98 - 2200	418	SB-02-53	528
BENZO(A)ANTHRACENE	0/11				21/38	49 - 5200	598	SB-02-53	882
BENZO(A)PYRENE	0/11				22/39	44 - 3800	545	SB-02-53	810
BENZO(B)FLUORANTHENE	1/11	58	BG-13	58	21/38	51 - 4900	626	SB-02-53	941
BENZO(G,H,I)PERYLENE	0/11				19/38	51 - 2100	330	TP10-0207	451

TABLE 4-12
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
BENZO(K)FLUORANTHENE	1/11	46	BG-13	46	20/38	23 - 2200	365	TP10-0207	546
BIS(2-ETHYLHEXYL)PHTHALATE	1/11	50	BG-16	50	6/39	46 - 2200	414	SB-02-41	700
BUTYLBENZYL PHTHALATE	0/11				3/33	55 - 110	364	SB-02-22	110.0
CARBAZOLE	0/11				6/38	91 - 1300	413	SB-02-53	480
CHRYSENE	1/11	51	BG-13	51	22/38	42 - 4900	587	SB-02-53	922
DI-N-BUTYL PHTHALATE	0/11				7/38	46 - 4200	448	SB-02-41	651
DIBENZO(A,H)ANTHRACENE	0/11				6/38	62 - 450	365	SB-02-53	417
DIBENZOFURAN	0/11				5/38	88 - 570	379	SB-02-53	417
DIETHYL PHTHALATE	0/11				2/38	48 - 67	366	SB-02-56-MAX	48.0
FLUORANTHENE	1/11	92	BG-13	92	22/38	68 - 13000	1,105	SB-02-53	1,711
FLUORENE	0/11				7/38	66 - 1000	410	SB-02-53	498
INDENO(1,2,3-CD)PYRENE	0/11				17/38	29 - 2500	451	TP10-0207	636
NAPHTHALENE	0/11				4/38	51 - 250	369	SB-02-53	250
PENTACHLOROPHENOL	0/11				1/38	62	883	SB-02-08	62.0
PHENANTHRENE	1/11	51	BG-13	51	18/38	43 - 9900	775	SB-02-53	1,181
PYRENE	1/11	100	BG-13	100	23/38	42 - 9800	983	SB-02-53	1,640
ALDRIN	0/23				1/40	3.6	1.30	SB-02-08	1.42
ALPHA-CHLORDANE	0/23				2/40	2.9 - 5.9	1.42	SB-02-27	1.59
AROCLOR-1248	0/23				1/42	110	26.4	SB-02-27	29.1
AROCLOR-1254	1/23	51	BG-13	41.3	5/42	11 - 1150	48.0	SB-02-07	37.5
AROCLOR-1260	0/23				7/42	9 - 1600	78.8	SB-02-07	65.3
DIELDRIN	0/23				2/40	4.3 - 5.8	2.60	SB-02-42	2.87
ENDOSULFAN II	0/23				2/39	2.4 - 8.5	2.17	SB-02-27	2.34
ENDOSULFAN SULFATE	0/21				1/40	9.3	2.63	TP11-0209	2.90
ENDRIN	0/23				6/40	2.1 - 20	3.78	SB-02-27	4.46
ENDRIN KETONE	0/23				3/40	1.2 - 5.5	2.51	SB-02-27	2.75
GAMMA-BHC (LINDANE)	0/23				1/40	2.5	1.29	SB-02-02	1.39
GAMMA-CHLORDANE	0/23				2/38	2.3 - 3.4	1.35	SB-02-08	1.50
HEPTACHLOR EPOXIDE	0/23				1/40	3.5	1.30	SB-02-08	1.42
HEXAVALENT CHROMIUM	0/0				5/13	0.00153 - 0.00359	0.0010	SB-02-24	0.0036
4,4'-DDE	1/23	820	BG-12	15.3	3/40	7.9 - 82	4.80	SB-02-42	4.45
4,4'-DDT	1/23	1440	BG-12	21.5	7/39	1.8 - 150	8.19	SB-02-42	6.16
XYLENES, TOTAL	0/21				5/53	2.8 - 38	36.1	SB-02-32	20.7
OCDD	0/0				4/5	0.25 - 0.68	0.38	SB-02-40	0.68
OCDF	0/0				1/5	0.25	0.10	SB-02-42	0.25
4,4'-DDD	1/23	16	BG-12	3	4/40	2.3 - 45	3.86	SB-02-08	3.92
2-METHYLNAPHTHALENE	0/11				3/38	110 - 360	375	SB-02-33	360

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.
Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SOIL BORING SAMPLE LOCATIONS ADDED.	LDL			

DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS SCREENING CRITERIA EXCEEDANCES
AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMNSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Isa DATE 4/10/00
DRAWING NO. FIGURE 4-13 REV. 1

AREA-A_OU-6/7603tm01.dwg

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were noted to a depth of 12.5 feet in TP-1 and 11 feet in TP-2. Two of the three borings were drilled on the northern side of Site 3 and one was drilled on the southern side. The two northern borings found fill materials to a depth of 4 feet, and one of these borings reached perched water at about 5 feet. In the other northern boring, clean fill or native soils were noted to a depth of 5 feet. The southern boring reached fill material at 2.6 feet and clean fill to a depth of 7 feet.

VOC vapors were detected from 2.5 to 3 feet below the ground in TP-1 and TP-2. In TP-1, vapor readings ranged from 40 to 60 ppm, and readings from TP-2 varied between 20 and 40 ppm. Boring SB-03-10 detected readings of 4 ppm from the sample that was collected at this location.

Waste materials noted in the Site 3 borings during the Phase III RI included ash, charred debris, pieces of glass, black plastic hose, and metal debris. These materials appeared consistent with the presence of a burn pit reported for this site.

4.4.1 Site 3 Geophysical Survey Results

Both the terrain conductivity and inphase readings from the Phase III EM survey in the vicinity of Site 3 indicated the presence of a buried utility or utilities crossing this area roughly parallel to nearby Jacksonville Road (see Figure 4-2). No EM anomalies related to suspected buried waste were observed in the Site 3 portion of Area A. Interference from buried utilities was expected to mark such anomalies, if present, along the southeastern and eastern portions of this area (see Figure 4-3).

4.4.2 Site 3 Soil Gas Survey Results

Low levels of volatile organics were found in the soil gas samples collected at Site 3 during Phase III. Figures 4-5, 4-6, and 4-7 display the soil gas survey results obtained at Site 3. The PID indicated that only three soil gas locations had levels between 0.2 and 1.5 ppm. These points were located north and east of the suspected location of the Site 3 burn pit. All remaining PID measurements were non-detect.

Only a few soil gas samples were collected from Site 3 during Phase III due to OU-1 construction activities. Portions of this site may lie beneath the paved entrance road.

4.4.3 Site 3 Surface Soil Results

4.4.3.1 Pre-Removal Sample Results

Tables 4-13 and 4-14 provide the occurrence and distribution of inorganics and organics in background and site-related surface soil samples for Site 3 based on the RI sampling results. Surface soil clean-up goals were established for four compounds identified in the RIs and supplemental investigation. The compounds targeted were anthracene, benz(a)anthracene, benzo(a)pyrene, and fluoranthene. Figure 4-14 details the area of soil excavation within Site 3. Removal at Site 3 consisted of one excavation, approximately 65 feet by 30 feet in size, located adjacent to Jacksonville Road. As reported in the May 1999 Post Removal Summary Report Area A, Sites 1, 2, and 3 (TtNUS, 1999a), surface soils, gravel, and deteriorated asphalt paving were removed from the area to depths between 2 to 3 feet. Note that the excavated area appeared to be outside the estimated location of Site 3.

4.4.3.2 Post-Removal Sample Results

Table 4-15 presents the occurrence and distribution of organics and inorganics in Site 3 surface soils samples remaining following the removal action. Figure 4-15 details those Site 3 sample locations where concentrations exceeded screening criteria and maximum background concentrations. In all four locations, benzo(a)pyrene was the only compound with concentrations greater than the screening criteria. However, all the concentrations were below the benzo(a)pyrene clean-up goal (2,500 ug/kg) established for the Site 3 removal action. In general, the clean-up goals were established at concentrations that were protective of human health under non-residential exposure scenarios. The removal action, therefore, did reduce the levels of the targeted compounds (anthracene, benz(a)anthracene, benzo(a)pyrene, and fluoranthene) in Site 3 soils.

4.4.4 Site 3 Subsurface Soil Results

Based on the Phase III RI sampling results, excavation of subsurface soils in Site 3 was not proposed as part of the 1998 removal action. Table 4-16 provides the current occurrence and distribution of organics and inorganics in background and site-related subsurface soils. Figure 4-16 details those subsurface sample locations where contaminant concentrations exceeded screening criteria. Organic compounds whose concentrations exceeded screening criteria were benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, and Aroclor 1254. Inorganic compounds that were exceeded included lead (in three samples) and arsenic (in 1 sample). Benzo(a)pyrene was the compound most frequently exceeded, however, six of the levels were below the

TABL

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SITE 3 SURFACE SOIL

NAWC WARMINSTER, PENNSYLVANIA

(mg/kg)

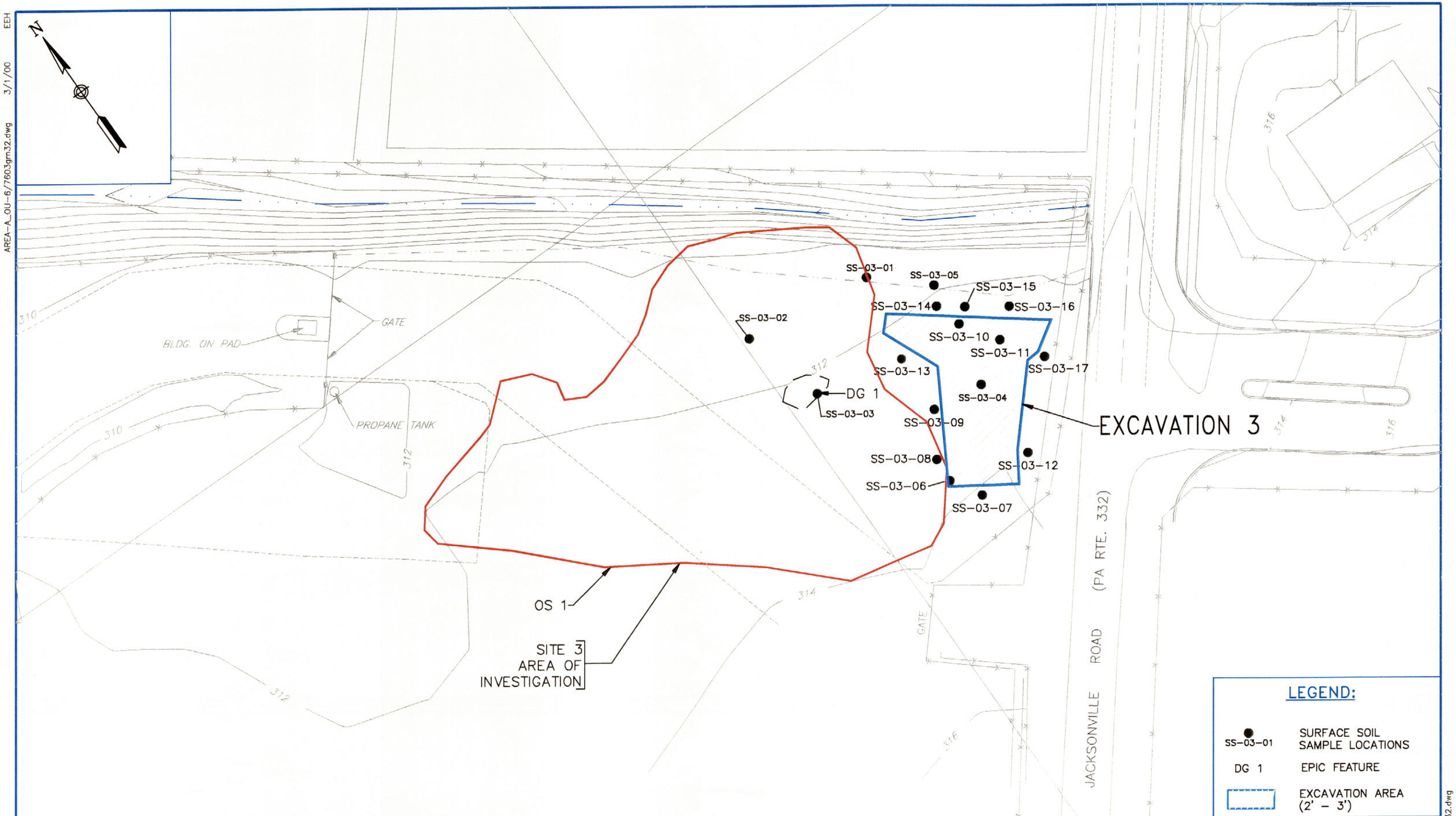
SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
ALUMINUM	31 / 31	4780 - 18100	15282	5 / 5	8440 - 12800	12030
ARSENIC	27 / 31	0.28 - 12.1	10.498232	5 / 5	3.5 - 7.8	7.49
BARIUM	27 / 29	34.1 - 225	74.12	5 / 5	59.8 - 98	93.88
BERYLLIUM	27 / 31	0.31 - 1.7	0.90	5 / 5	0.75 - 0.91	0.90
CALCIUM	25 / 29	240 - 1910	773	5 / 5	1100 - 22100	22100
CHROMIUM	31 / 31	7.9 - 35.3	21.59	5 / 5	16.2 - 36.8	35.30
COBALT	27 / 30	1.6 - 22.1	10.32	5 / 5	6.6 - 9.7	9.7
COPPER	29 / 31	3.6 - 30.6	13.56	5 / 5	11 - 42.3	42.3
CYANIDE	0 / 21	-	-	1 / 3	0.51	0.51
IRON	31 / 31	6980 - 410500	54527	5 / 5	14800 - 24200	22462
LEAD	31 / 31	1.6 - 96.5	16.69	5 / 5	15.3 - 30.4	30.31
MAGNESIUM	27 / 31	518 - 4960	2472	5 / 5	1700 - 9870	9870
MANGANESE	31 / 31	30.9 - 2010	527.88	5 / 5	337 - 1180	1180
NICKEL	20 / 27	4.1 - 21.7	14.40	4 / 4	10.5 - 20.2	20.2
POTASSIUM	27 / 29	89.1 - 3050	886	5 / 5	492 - 2510	2510
SODIUM	5 / 20	55.2 - 86.7	86.7	3 / 3	147 - 3620	3620
THALLIUM	3 / 31	0.37 - 0.42	0.42	1 / 5	1.1	0.80
VANADIUM	31 / 31	15.4 - 45	33.01	5 / 5	22.7 - 42.4	41.58
ZINC	27 / 29	9 - 60	31.34	5 / 5	34.5 - 167	120.08

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TABLE 4-14
OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SITE 3 SURFACE SOIL
NAWC WARMINSTER, PENNSYLVANIA
(ug/kg)

SUBSTANCE	BACKGROUND			SITE-RELATED		
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	REPRESENTATIVE CONCENTRATION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION*	REPRESENTATIVE CONCENTRATION
4,4'-DDT	1 / 21	1440	188.58	2 / 5	7.1 - 15	15
ENDRIN	0 / 21	-	-	1 / 5	4.4	3.45
GAMMA-BHC	0 / 21	-	-	3 / 5	1.9 - 9.4	6.53
ACENAPHTHYLENE	0 / 11	-	-	1 / 5	39	39
ANTHRACENE	0 / 11	-	-	1 / 5	840	840
BENZ(A)ANTHRACENE	0 / 11	-	-	5 / 5	56 - 3400	2318
BENZO(A)PYRENE	0 / 11	-	-	3 / 5	52 - 3000	3000
BENZO(B)FLUORANTHENE	1 / 11	58	58	5 / 5	130 - 4500	3053
BENZO(G,H,I)PERYLENE	0 / 11	-	-	3 / 5	59 - 1700	1700
BENZO(K)FLUORANTHENE	1 / 11	46	46	2 / 5	79 - 1800	1800
CARBAZOLE	0 / 11	-	-	1 / 5	670	670
CHRYSENE	1 / 11	51	51	5 / 5	79 - 2400	2400
FLUORANTHENE	1 / 11	92	92	3 / 5	120 - 6900	6900
FLUORENE	0 / 11	-	-	1 / 5	420	420
INDENO(1,2,3-CD)PYRENE	0 / 11	-	-	3 / 5	43 - 1700	1700
PYRENE	1 / 11	100	100	5 / 5	100 - 4500	4500

* = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES



DRAWN BY LDL	DATE 3/14/00	Tetra Tech NUS, Inc.	SOIL EXCAVATION AREA AREA A – SITE 3 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY RO DATE 4/23/00
DRAWING NO. FIGURE 4-14
REV.

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TABLE 15

OCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 3 SURFACE SOIL (POST-REMOVAL)

NAWC WARMINSTER, PENNSYLVANIA

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	5/5	7510 - 12800	9560	SS-03-02	12000.2929
ARSENIC	25/29	0.28 - 12.1	BG-11	11.7	5/5	3.5 - 7.9	5.9	SS-03-06	7.9
BARIUM	25/29	34.1 - 225	BG-28	87.1	5/5	66.7 - 99	83.3	SS-03-06	99
BERYLLIUM	25/29	0.31 - 1.7	BG-23-MAX	0.88	5/5	0.82 - 0.97	0.88	SS-03-06	0.97
CALCIUM	23/29	240 - 1910	BG-24	781	5/5	4060 - 30700	18732	SS-03-06	27905.1078
CHROMIUM	29/29	7.9 - 35.3	BG-12	21.7	5/5	16.2 - 36.8	25.68	SS-03-05	36.8
COBALT	25/29	1.6 - 22.1	BG-23-MAX	10.4	5/5	7.9 - 11.7	9.38	SS-03-06	11.0121
COPPER	27/29	3.6 - 30.6	BG-29	14.1	5/5	11 - 42.3	23.04	SS-03-05	42.3
CYANIDE	0/20				1/2	0.51	0.385	SS-03-02	0.51
IRON	29/29	6980 - 410500	BG-04	35,030	5/5	14800 - 28600	20560	SS-03-06	28406.1576
LEAD	29/29	1.6 - 96.5	BG-13	16.4	5/5	18.2 - 30.4	23.14	SS-03-02	28.6973
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	5/5	3280 - 12300	8476	SS-03-06	11642.437
MANGANESE	29/29	30.9 - 2010	BG-28	604	5/5	401 - 1180	701	SS-03-01	1180
NICKEL	18/29	4.1 - 21.7	BG-23-MAX	11.1	4/5	10.5 - 21.5	14.93	SS-03-06	20.7926
POTASSIUM	25/29	89.1 - 3050	BG-24	997	5/5	699 - 2510	1670	SS-03-02	2464.387
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	4/5	147 - 3620	861.4	SS-03-02	3620
THALLIUM	3/29	0.37 - 0.42	BG-23-MAX	0.42	1/5	1.1	0.489	SS-03-02	1.1
VANADIUM	29/29	15.4 - 45	BG-12	32.2	5/5	22.7 - 50.7	34.6	SS-03-06	46.2422
ZINC	25/29	9 - 60	BG-13	30	5/5	34.5 - 167	71.58	SS-03-05	167
ACENAPHTHYLENE	0/11				5/8	33 - 120	545.875	SS-03-07	120
ANTHRACENE	0/11				9/13	65 - 220	417.230769	SS-03-08	220
BENZO(A)ANTHRACENE	0/11				13/13	56 - 1200	619.692308	SS-03-08	786.3156
BENZO(A)PYRENE	0/11				11/13	52 - 1400	907.076923	SS-03-15	1203.5322
BENZO(B)FLUORANTHENE	1/11	58	BG-13	58	8/8	130 - 1300	693.75	SS-03-08	947.0797
BENZO(G,H,I)PERYLENE	0/11				6/8	59 - 320	599.875	SS-03-08	320
BENZO(K)FLUORANTHENE	1/11	46	BG-13	46	5/8	79 - 1000	888.625	SS-03-08	1000
CHRYSENE	1/11	51	BG-13	51	8/8	79 - 1200	621.125	SS-03-05	880.333
DIBENZO(A,H)ANTHRACENE	0/11				3/8	35 - 99	642.125	SS-03-08	99
FLUORANTHENE	1/11	92	BG-13	92	11/13	120 - 3300	1599.230769	SS-03-15	2024.6605
FLUORENE	0/11				2/8	28 - 41	673.625	SS-03-07	41
INDENO(1,2,3-CD)PYRENE	0/11				6/8	43 - 380	612.875	SS-03-08	380
PHENANTHRENE	1/11	51	BG-13	51	7/8	40 - 1100	661.25	SS-03-05	1100
PYRENE	1/11	100	BG-13	100	8/8	100 - 1800	950	SS-03-05	1345.5579
1,1,2,2-TETRACHLOROETHANE	0/11				1/1	1	1	SS-03-06	1
BROMOMETHANE	0/11				1/1	21	21	SS-03-06	21
4,4'-DDT	1/23	1440	BG-12	21.5	2/4	7.1 - 15	6.45	SS-03-03	15
GAMMA-BHC (LINDANE)	0/23				2/4	1.9 - 2.5	1.5625	SS-03-03	2.4756

Notes:

* - Minimum and maximum detected site-related concentrations are based on duplicate samples.

Units are mg/kg for inorganics, ug/kg for organics.

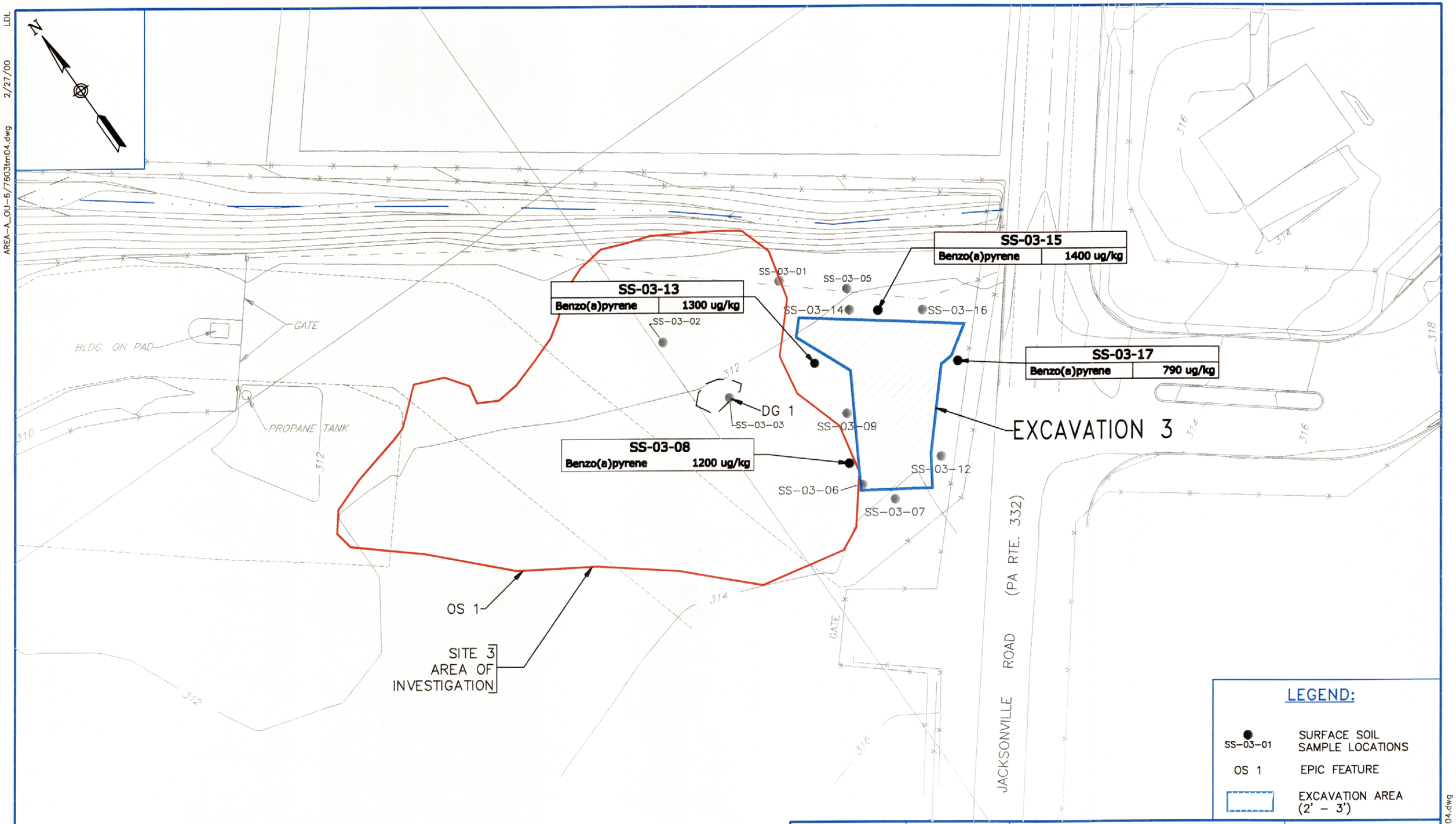
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.

Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.

The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.

Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.

Number of samples may vary based on the number of usable results.



LEGEND:

SS-03-01	SURFACE SOIL SAMPLE LOCATIONS
OS 1	EPIC FEATURE
	EXCAVATION AREA (2' – 3')

0 40 80
SCALE IN FEET

DRAWN BY LDL	DATE 3/14/00	Tetra Tech NUS, Inc.	POST-REMOVAL SURFACE SOIL CONCENTRATIONS SCREENING CRITERIA EXCEEDANCES AREA A – SITE 3 FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA
CHECKED BY	DATE		
REVISED BY	DATE		
SCALE AS NOTED			

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY TRA DATE 4/23/00
DRAWING NO. FIGURE 4-15 REV.

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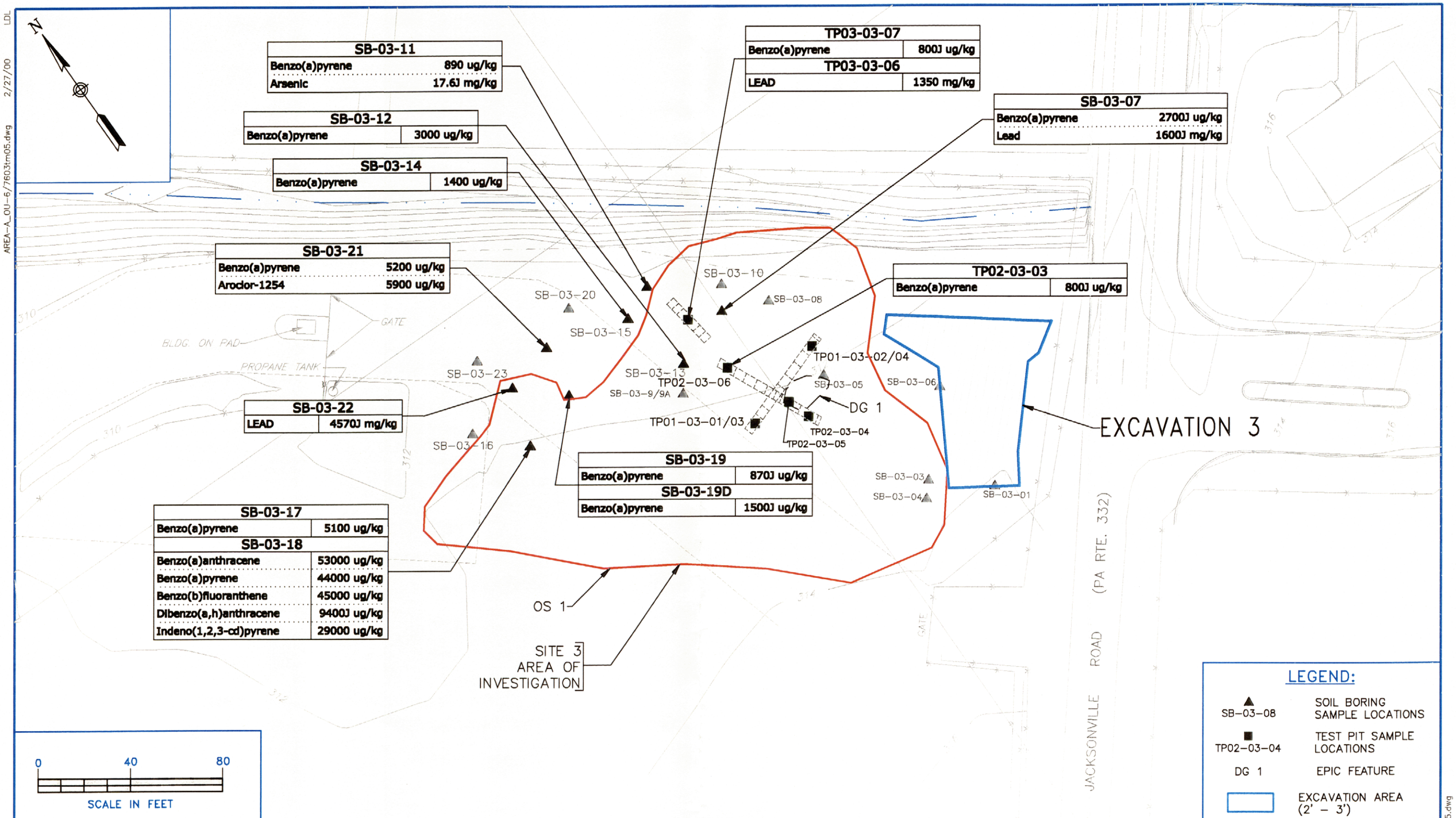
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA
PAGE 1 OF 2

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	29/29	6960 - 29500	12725.17241	TP03-03-06	14,010
ANTIMONY	1/29	13.6	BG-16	4.11	9/29	0.42 - 16.6	5.410862	TP03-03-06	9.67
ARSENIC	25/29	0.28 - 12.1	BG-11	11.7	25/29	1.1 - 17.6	5.022414	SB-03-11	6.74
BARIUM	25/29	34.1 - 225	BG-28	87.1	28/29	50.3 - 1530	289.194828	TP03-03-06	419
BERYLLIUM	25/29	0.31 - 1.7	BG-23-MAX	0.88	25/29	0.63 - 3.1	1.122759	TP02-03-04	1.36
CADMIUM	0/29				15/29	1.1 - 67.1	7.959828	TP03-03-06	32.9
CALCIUM	23/29	240 - 1910	BG-24	781	27/29	600 - 42500	10743.86207	TP03-03-06	22,175
CHROMIUM	29/29	7.9 - 35.3	BG-12	21.7	28/29	13.6 - 83.4	30.812069	TP03-03-06	39.7
COBALT	25/29	1.6 - 22.1	BG-23-MAX	10.4	28/29	4.9 - 23.4	10.698276	TP02-03-04	12.3
COPPER	27/29	3.6 - 30.6	BG-29	14.1	28/29	5.2 - 3760	332.32931	TP03-03-06	1,390
IRON	29/29	6980 - 410500	BG-04	35,030	29/29	10900 - 69500	23293.10345	SB-03-11	26,714
LEAD	29/29	1.6 - 96.5	BG-13	16.4	35/35	5 - 4570	329.631429	SB-03-22	1,016
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	27/29	1710 - 15600	5588.103448	SB-03-07	7,149
MANGANESE	29/29	30.9 - 2010	BG-28	604	29/29	99.1 - 2330	732.865517	TP01-03-03	1,073
MERCURY	1/29	0.37	BG-23-MAX	0.05	16/29	0.15 - 9.7	1.263621	SB-03-07	8.20
NICKEL	18/29	4.1 - 21.7	BG-23-MAX	11.1	29/29	6.6 - 230	34.548276	SB-03-11	44.7
POTASSIUM	25/29	89.1 - 3050	BG-24	997	29/29	379 - 3710	1153.931034	TP02-03-04	1,407
SELENIUM	0/29				7/29	0.54 - 2.9	0.58	TP03-03-06	0.68
SILVER	0/29				16/29	0.96 - 368	33.952759	TP03-03-06	368
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	28/29	48.9 - 1460	341.551724	TP03-03-06	486
THALLIUM	3/29	0.37 - 0.42	BG-23-MAX	0.4	2/29	1.1 - 1.4	0.410862	SB-03-12	0.47
VANADIUM	29/29	15.4 - 45	BG-12	32.2	29/29	8.9 - 284	47.658621	SB-03-12	59.0
ZINC	25/29	9 - 60	BG-13	30	28/29	21.6 - 9100	724.763793	TP03-03-06	1,970
1,2-DICHLOROETHENE (TOTAL)	0/21				1/29	4	106.856897	SB-03-23-MAX	4.00
2-BUTANONE	0/21				8/29	5.6 - 1000	119.144828	TP01-03-01	128
ACETONE	0/21				6/29	8.4 - 140	116.651724	TP01-03-02	140
BENZENE	0/21				1/29	5.1	106.987931	SB-03-11	5.10
CARBON DISULFIDE	0/21				6/29	1.4 - 13	106.893103	SB-03-11	13.0
CHLOROBENZENE	0/19				2/29	11 - 140	111.581034	TP03-03-06	127
CHLOROFORM	0/19				2/29	1	106.581034	TP02-03-04, TP02-03-05	1.00
ETHYLBENZENE	0/21				3/29	4 - 130	112.708621	SB-03-12	130
METHYLENE CHLORIDE	0/21				1/29	3300	176.512069	SB-03-09	159
TOLUENE	3/21	2	BG-17	2	9/29	2 - 120	110.531034	SB-03-05	120
1,4-DICHLOROBENZENE	1/11	43	BG-11	43	2/20	52 - 120	1518.6	TP03-03-06	120
ACENAPHTHENE	0/11				9/26	110 - 4400	1422.307692	SB-03-18	3,646
ACENAPHTHYLENE	0/11				9/26	36 - 1200	1556.403846	SB-03-17	1,200
ANTHRACENE	0/11				13/26	3.6 - 21000	2153.523077	SB-03-18	21,000
BENZO(A)ANTHRACENE	0/11				19/26	1.2 - 53000	3725.276923	SB-03-18	37,125
BENZO(A)PYRENE	0/11				19/26	3 - 44000	3407	SB-03-18	24,550
BENZO(B)FLUORANTHENE	1/11	58	BG-13	58	18/26	1.7 - 45000	3578.142308	SB-03-18	35,976
BENZO(G,H,I)PERYLENE	0/11				15/26	100 - 26000	2251.498077	SB-03-18	15,030
BENZO(K)FLUORANTHENE	1/11	46	BG-13	46	16/26	3 - 34000	2750.615385	SB-03-18	32,962
BIS(2-ETHYLHEXYL)PHTHALATE	1/11	50	BG-16	50	2/20	280 - 4000	1681.5	SB-03-10	4,000
BUTYL BENZYL PHTHALATE	0/11				1/20	41	1525.05	TP03-03-07	41.0

TABLE 4-16
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA
PAGE 2 OF 2

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
CARBAZOLE	0/11				5/20	63 - 1000	1505.45	SB-03-21	1,000
CHRYSENE	1/11	51	BG-13	51	19/26	1.1 - 51000	3703.403846	SB-03-18	38,764
DI-N-BUTYL PHTHALATE	0/11				2/20	51 - 53	1482.225	SB-03-12	53.0
DI-N-OCTYL PHTHALATE	0/11				1/20	320	1538.5	SB-03-10	320
DIBENZO(A,H)ANTHRACENE	0/11				9/26	46 - 9400	1544.190385	SB-03-18	9,291
DIBENZOFURAN	0/11				4/20	57 - 300	1521.6	SB-03-12	300
DIETHYL PHTHALATE	0/11				1/20	86	1523.8	TP03-03-06	86.0
FLUORANTHENE	1/11	92	BG-13	92	20/26	1.9 - 120000	6676.534615	SB-03-18	64,827
FLUORENE	0/11				10/26	31 - 4500	1405.382692	SB-03-18	4,500
HEXACHLOROETHANE	0/11				1/20	640	1554.75	TP01-03-03	640
INDENO(1,2,3-CD)PYRENE	0/11				16/26	3.2 - 29000	2475.776923	SB-03-18	10,710
NAPHTHALENE	0/11				6/26	120 - 450	1560	SB-03-19-MAX	450
PHENANTHRENE	1/11	51	BG-13	51	18/26	1.8 - 71000	4634.223077	SB-03-18	36,617
PHENOL	0/11				1/20	150	1530	SB-03-10	150
PYRENE	1/11	100	BG-13	100	20/26	3.3 - 97000	5541.357692	SB-03-18	36,810
ALDRIN	0/23				5/12	2 - 180	19.4125	SB-03-21	123
AROCLOR-1242	0/21				2/19	36 - 84	46.342105	TP03-03-06	58.7
AROCLOR-1248	0/23				1/19	120	47.684211	SB-03-12	61.7
AROCLOR-1254	1/23	51	BG-13	41.3	6/19	64 - 5900	380.631579	SB-03-21	597
AROCLOR-1260	0/21				3/19	59 - 290	70.842105	TP01-03-03	118
ENDRIN	0/23				4/13	4.4 - 24	7.257692	SB-03-21	15.7
GAMMA-BHC (LINDANE)	0/21				1/12	3.5	3.070833	TP01-03-02	3.50
GAMMA-CHLORDANE	0/23				2/13	8 - 14	3.980769	SB-03-21	9.68
HEPTACHLOR EPOXIDE	0/21				1/13	6.1	3.111538	TP01-03-03	5.81
4,4'-DDE	1/21	820	BG-12	820	4/13	16 - 42	11.673077	TP01-03-01	42.0
4,4'-DDT	1/23	1440	BG-12	21.5	3/13	11 - 31	9.111538	SB-03-07	26.1
XYLENES, TOTAL	0/21				4/29	2.4 - 580	129.794828	SB-03-11	220
OCDD	0/0				2/4	0.76 - 2.2	0.9525	TP01-03-01	2.20
4,4'-DDD	1/23	16	BG-12	3	5/12	11 - 150	37.9	TP01-03-02	150
2-METHYLNAPHTHALENE	0/11				4/20	86 - 690	1538.2	TP01-03-03	690

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.
Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SOIL BORING SAMPLE LOCATIONS REVISED.	LDL			

DRAWN BY LDL DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SCREENING CRITERIA EXCEEDANCES
AREA A – SITE 3
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Tea DATE 4/23/00
DRAWING NO. FIGURE 4-16 REV. 1

LDL 2/27/00 AREA-A_OU-6/7603tm05.dwg

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removal action clean-up goal (i.e., 2,500 ug/kg) for the Site 3 surface soil removal action. Sample SB-03-18, located along the eastern edge of the Site 3 investigation area, exhibited the highest observed levels of the detected PAH compounds. The PAH compounds detected in the subsurface are most likely the result of activities from the reported burn pit that was used for the disposal of solvents, paints, roofing materials, and other unspecified chemicals. The pit was reported to be approximately 10 feet in depth.

4.5 IMPOUNDMENT AREA

A total of 70 soil borings were located in this general area (see Figure 2-11). The locations were based on EM surveys, soil gas surveys, EPIC photographs, and previous investigations. Three of the confirmation borings encountered waste in a band from 4 to 5 feet bgs. Fill material ranged in depth from 0 to 3 feet, and clean fill and native soils ranged from 3 to 10 feet. The results of subsurface work at each impoundment are described below.

IM1

Five borings (IM101, IM103, IM104, IM105, and IM106) were located in this area. Two of the five borings, IM104 and IM106, encountered waste at a depth between 4 and 5 feet. The waste material was described as a rusty red sticky clay. In each of the soil borings, a layer from ground surface to 3 feet was fill material including rocks, clay, slag, coal, and roots. Clean fill or native soils were encountered from 3 to 10 feet. No HNu readings were recorded above background at any location.

IM2

Seven borings (IM201 through IM207) were located in this area. No wastes were encountered in any of the borings. Fill material ranged in depth from ground surface to 4 feet. The fill material contained coal, brick, roots, ash, and cinders. Clean fill or native soils were encountered to a depth of 8 feet. No HNu readings were recorded above background at any location.

IM3

Nine borings (IM301 through IM309) were located in this area. No waste materials were encountered in any of the borings. Clean fill of native soils were encountered from ground surface to 6 to 8 feet. HNu readings were encountered in two borings, IM301 and IM302, at levels ranging from 1 to 87 ppm above background.

IM4

A total of 13 borings were collected in this area, which was beneath the existing eastern lagoon. No wastes were encountered in any of the borings. Fill materials ranged in depth from ground surface to 2 feet. Concrete, crushed stone, and screenings were encountered in the fill material. Clean fill or native soils were encountered from 2 to 5 feet bgs. HNu readings from 3 to 8 ppm above background were recorded in boring IM403.

IM5

Seven borings (IM501 through IM507) were drilled through this impoundment, which was also located beneath the eastern concrete lagoon. No waste materials were encountered in any of the borings. The boring logs for three borings did note a slight fuel odor; however, no HNu readings above background were noted.

IM6

Five borings (IM601 through IM605) were drilled through impoundment IM6, which was located under the western concrete lagoon in this area. No wastes were encountered in any of the borings. Fill material ranged in depth from ground surface to 1.5 feet and consisted of concrete, crushed stone, and screenings. Clean fill or native soils were encountered from 1.5 to 5 feet bgs. No HNu readings were recorded above background in any of the borings.

IM7

Ten borings (IM701 through IM710) were located in this area. One of the borings (IM705) encountered waste at a depth between 4 and 5 feet. The waste material consisted of a sticky red clay. In addition, four borings encountered clean fill or native soils from 6 to 8 feet. No HNu readings were recorded above background at any location.

IM8

A total of 14 borings were drilled in the vicinity of IM-8 during the OU-1 pre-design investigation and during the construction of the groundwater treatment plant. These borings ranged in depth from 4 to 14 feet bgs. Brown, silty clay with little sandstone was encountered in most of these borings. Highly weathered red shale was noted at the bedrock interface. No significant waste materials were found, and no HNu readings above background were recorded.

4.5.1 Impoundment Area Geophysical Survey Results

No significant EM survey anomalies unrelated to buried utilities or other known cultural features were observed in the northwestern portion of Area A where the former surface impoundments were located. The work was conducted as part of the Phase III RI.

4.5.2 Impoundment Area Soil Gas Survey Results

The most recent soil gas survey in the former Impoundment Area was conducted as part of the Phase III RI. No additional surveys were conducted subsequent to that work. As outlined in the Phase III RI Report (B&R Environmental, 1996a), the significant soil gas results (Figures 4-5 through 4-7) for this general area are as follows:

- Several areas of positive soil gas detections were found near and within this area, which includes the existing concrete lagoons.

- Detected chemicals include PCE, CCl_4, 1,1,1,-TCA, benzene, other BTEX compounds, TCE, and trans-1,2-DCE.

- Very low levels of PCE were detected at soil gas locations beneath the concrete lagoons, IM2, and IM3. Concentrations ranged from 0.08 to 0.42 ug/l.

- Low levels of CCl_4 were found at soil gas locations beneath the concrete lagoons, IM7, and IM8. Concentrations ranged from 0.01 to 3.6 ug/l.

- Very low levels of 1,1,1-TCA were detected beneath the concrete lagoons and at one location within IM2. Concentrations ranged from 0.08 to 0.96 ug/l.

- Benzene was found beneath the eastern concrete lagoon and within IM7 and IM8. Concentrations ranged from 2.1 to 64 ug/l. The highest benzene levels were near the fuel farm area beneath the lagoon.

- Other BTEX compounds were detected beneath the eastern concrete lagoon, IM3, and IM8. Concentrations ranged from 1.5 to 170 ug/l. The highest BTEX levels were near the fuel farm area beneath the lagoon.

- TCE was detected at soil gas locations throughout the vicinity of the former impoundments. Higher concentrations were found along the northern edge of the Impoundment Area. These levels ranged from 0.11 to 7.1 ug/l. The highest TCE concentration was found within IM1.

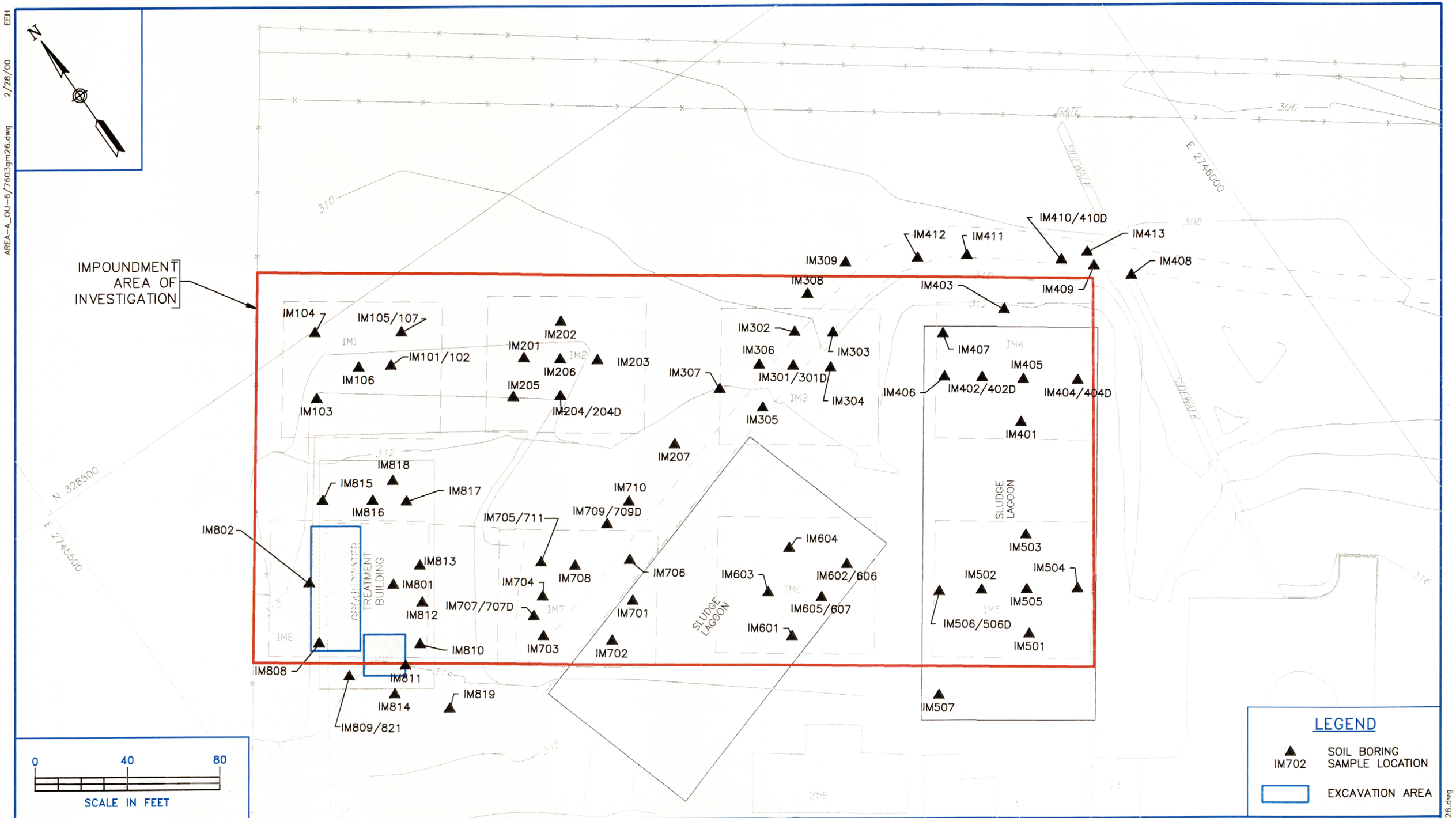
- Trans-1,2-DCE was detected throughout the Impoundment Area. Concentrations ranged from 1.5 to 28 ug/l. The highest trans-1,2-DCE levels were near the groundwater treatment plant.

- Higher VOC levels generally were found in the deeper soil gas samples taken at each soil gas location.

- In general, VOCs were more frequently detected beneath the concrete lagoons (i.e., IM4, IM5, IM6) than from any other former impoundment in this area. Soil gas samples from IM5 generally showed the highest soil gas readings.

4.5.3 Impoundment Area Subsurface Soil Results

No surface soil samples were collected from the former Impoundment Area during the RI scope of work. Based on subsurface samples collected during the RI, a limited excavation of contaminated soils in the Impoundment Area was conducted by the Navy in 1995. Figure 4-17 outlines the areas of soil excavation. Table 4-17 details the occurrence and distribution of organics and inorganics in background and the former Impoundment Area subsurface soils that remained after the soil excavation work. Concentration data obtained from the analysis of the former Impoundment Area subsurface soil samples were compared to federal and state soil screening criteria for industrial exposure scenarios. Figure 4-18 details those post-removal subsurface soil sample locations where contaminant concentrations exceeded both the highest observed background concentration and one of the screening criteria, as shown on the analytical summary tables contained in Appendix A. Benzo(a)pyrene was the only detected compound that exceeded the screening criteria; it was found in two samples. In sample IM107, collected from impoundment IM1, benzo(a)pyrene was detected at 3,000J ug/kg and in sample IM302, collected from impoundment IM3, benzo(a)pyrene was detected at 2,000J ug/kg.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SOIL BORING SAMPLE LOCATIONS ADDED.	LDL			

DRAWN BY LDL/EEH DATE 3/14/00
CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

IMPOUNDMENT AREA EXCAVATION AREAS
AREA A – IMPOUNDMENT AREA
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY RPA DATE 4/23/00
DRAWING NO. FIGURE 4-17
REV. 1

EEH 2/28/00 AREA-A_OU-6/7603gm26.dwg

442B254

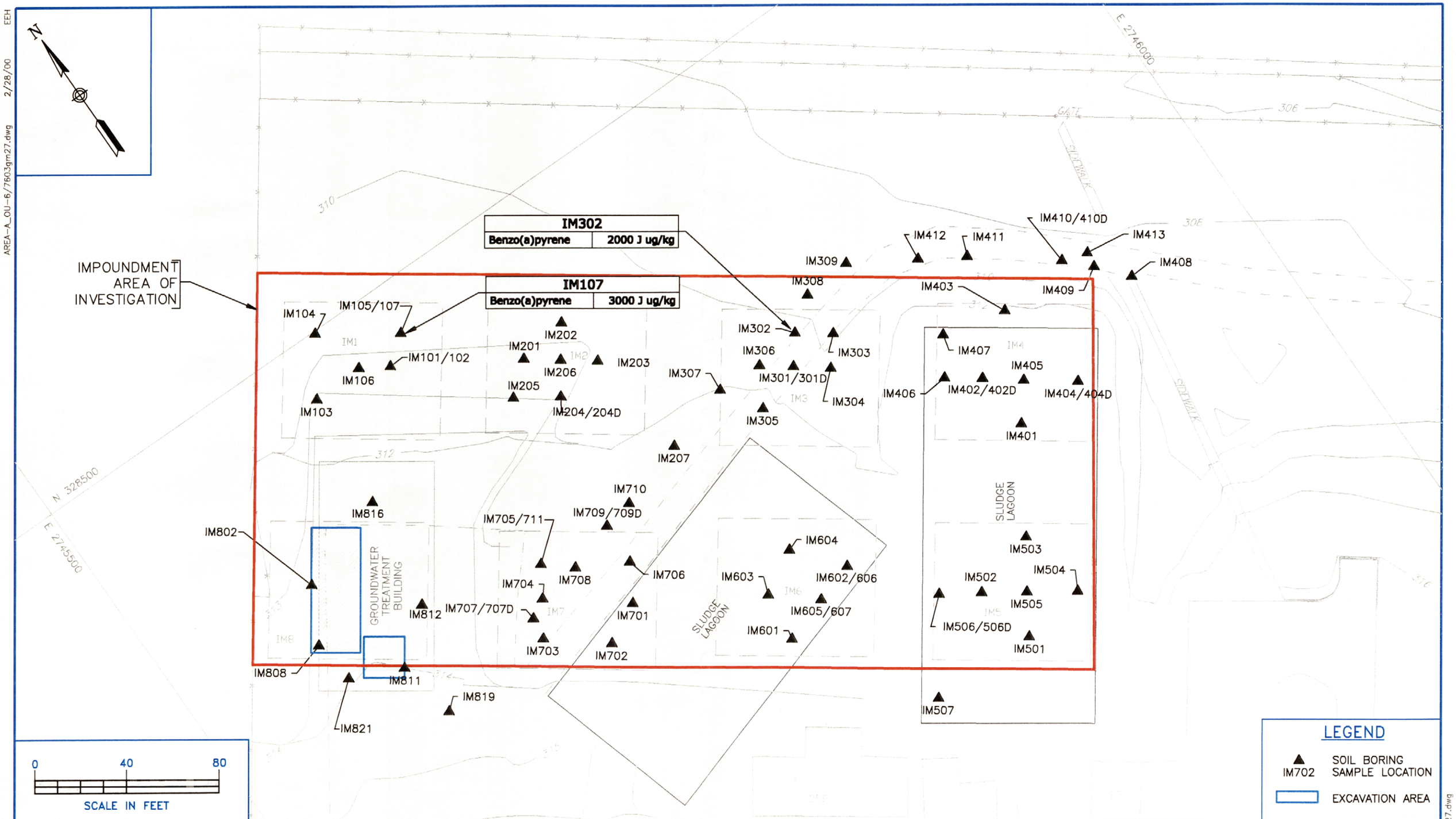
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA
PAGE 1 OF 2

	Background Data				Site-Related Data				
Substance	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
ALUMINUM	29/29	4780 - 18100	BG-12	15,226	65/65	4500 - 20100	11,340.31	IM409	12,081
ANTIMONY	1/29	13.6	BG-16	4.11	10/39	0.56 - 144	10.18	IM711	19.1
ARSENIC	25/29	0.28 - 12.1	BG-11	11.7	40/65	0.42 - 6.4	1.76	IM711	2.19
BARIUM	25/29	34.1 - 225	BG-28	87.1	65/65	45.5 - 316	101.15	IM711	107
BERYLLIUM	25/29	0.31 - 1.7	BG-23-MAX	0.88	56/65	0.37 - 6.7	1.04	IM503	1.11
CADMIUM	0/29				10/65	0.8 - 91.1	4.45	IM101A	2.86
CALCIUM	23/29	240 - 1910	BG-24	781	65/65	552 - 132000	6,993.69	IM711	5,540
CHROMIUM	29/29	7.9 - 35.3	BG-12	21.7	65/65	2.5 - 4730	251.92	IM711	210
COBALT	25/29	1.6 - 22.1	BG-23-MAX	10.4	64/65	2.2 - 61.4	14.78	IM711	15.8
COPPER	27/29	3.6 - 30.6	BG-29	14.1	49/65	2.5 - 707	27.34	IM711	32.9
CYANIDE	0/20				9/37	0.66 - 79.6	4.67	IM711	5.35
HEXAVALENT CHROMIUM	0/0				14/39	0.9 - 22.5	1.61	IM406	15.4
IRON	29/29	6980 - 410500	BG-04	35,030	65/65	3350 - 91700	19,845.54	IM101	22,086
LEAD	29/29	1.6 - 96.5	BG-13	16.4	58/65	0.59 - 89.8	14.13	IM711	17.9
MAGNESIUM	25/29	518 - 4960	BG-24	2,269	65/65	544 - 42800	3,766.94	IM301-MAX	4,143
MANGANESE	29/29	30.9 - 2010	BG-28	604	65/65	90.3 - 6090	1,077.24	IM503	1,298
MERCURY	1/29	0.37	BG-23-MAX	0.05	13/65	0.06 - 2.6	0.14	IM307	0.1
NICKEL	18/29	4.1 - 21.7	BG-23-MAX	11.1	65/65	3.3 - 62.7	17.73	IM101	19
POTASSIUM	25/29	89.1 - 3050	BG-24	997	62/65	189 - 5680	1,517.78	IM409	1,897
SILVER	0/29				14/65	0.59 - 373	11.45	IM711	5.85
SODIUM	4/29	55.2 - 86.7	BG-25	86.7	20/65	68.8 - 612	116.80	IM409	121
THALLIUM	3/29	0.37 - 0.42	BG-23-MAX	0.42	1/65	1.1	0.47	IM301-MAX	0.49
VANADIUM	29/29	15.4 - 45	BG-12	32.2	65/65	4.8 - 33.7	17.87	IM101A	19.4
ZINC	25/29	9 - 60	BG-13	30	49/65	9.9 - 327	44.21	IM711	49.2
2-METHYLNAPHTHALENE	0/11				1/30	44	293.97	IM505	44
4-METHYLPHENOL	0/11				1/30	160	297.33	IM307	160
ACENAPHTHYLENE	0/11				1/30	560	284.50	IM302	299
ANTHRACENE	0/11				1/30	510	282.83	IM302	297
BENZO(A)ANTHRACENE	0/11				8/30	49 - 2700	317.07	IM107	355
BENZO(A)PYRENE	0/11				8/30	45 - 3000	340.60	IM107	372
BENZO(B)FLUORANTHENE	1/11	58	BG-13	58	9/30	46 - 2800	351.83	IM107	386
BENZO(G,H,I)PERYLENE	0/11				7/30	53 - 1700	272.17	IM107	318
BENZO(K)FLUORANTHENE	1/11	46	BG-13	46	6/30	51 - 1100	250.07	IM107	288
BIS(2-ETHYLHEXYL)PHTHALATE	1/11	50	BG-16	50	16/30	45 - 320	224.63	IM711	285
CHRYSENE	1/11	51	BG-13	51	8/30	60 - 3300	357.03	IM107	378
DI-N-BUTYL PHTHALATE	0/11				4/30	55 - 110	272.60	IM201	110
DIBENZO(A,H)ANTHRACENE	0/11				1/30	400	305.83	IM410-MAX	34
FLUORANTHENE	1/11	92	BG-13	92	11/30	48 - 3700	395.53	IM107	419
FLUORENE	0/11				1/30	240	273.83	IM302	240
INDENO(1,2,3-CD)PYRENE	0/11				7/30	45 - 1300	255.60	IM107	321
PENTACHLOROPHENOL	0/11				1/30	120	696.83	IM711	120
PHENANTHRENE	1/11	51	BG-13	51	6/30	56 - 1900	277.13	IM302	311
PYRENE	1/11	100	BG-13	100	11/30	42 - 7000	531.83	IM107	502

TABLE 4-17
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Substance	Background Data				Site-Related Data				
	Frequency of Detection	Range of Positive Detections Min - Max	Location of Maximum	Exposure Point Concentration	Frequency of Detection	Range of Positive Detections Min - Max	Mean of All Data	Location of Maximum	Exposure Point Concentration
1,1,2,2-TETRACHLOROETHANE	0/19				1/59	2	95.04	IM605A	2
1,2-DICHLOROETHENE (TOTAL)	0/19				2/59	1 - 11	95.09	IM201	11
2-BUTANONE	0/19				3/59	6 - 23	87.76	IM101	23
4-METHYL-2-PENTANONE	0/19				1/59	450	101.71	IM504	76
ACETONE	4/19	8 - 12	BG-24	12	8/59	16 - 1100	264.58	IM503	523
CHLOROMETHANE	2/19	3	BG-27	3	1/59	2	79.02	IM406	2
ETHYLBENZENE	0/19				1/59	14	94.32	IM504	14
TETRACHLOROETHENE	0/19				1/59	10	94.76	IM403	10
TOLUENE	3/19	2	BG-17	2	1/59	8	95.13	IM101	8
TRICHLOROETHENE	0/19				6/59	2 - 15	94.11	IM504	15
4,4'-DDD	1/21	16	BG-12	3	11/30	0.11 - 150	13.07	IM501	21
4,4'-DDE	1/21	820	BG-12	15.3	7/30	0.29 - 3.7	2.80	IM501	3.47
4,4'-DDT	1/21	1440	BG-12	21.5	9/30	0.51 - 78	6.80	IM711	7.56
ALDRIN	0/21				1/30	2.3	1.54	IM301-MAX	1.65
ALPHA-CHLORDANE	0/21				1/30	0.25	1.47	IM309	0.25
AROCLOR-1242	0/21				1/30	31	29.25	IM309	31
AROCLOR-1254	1/21	51	BG-13	41.3	6/30	16 - 44	30.60	IM410-MAX	33.2
AROCLOR-1260	0/21				5/30	21 - 930	60.37	IM711	53.3
DELTA-BHC	0/21				2/30	0.067 - 9.9	1.60	IM711	2.11
DIELDRIN	0/21				6/30	0.046 - 21	2.57	IM711	5.32
ENDOSULFAN I	0/21				2/30	0.071 - 0.8	1.45	IM307	0.8
ENDOSULFAN II	0/21				4/30	0.11 - 19	3.13	IM711	4.36
ENDRIN	0/21				4/30	0.094 - 13	2.60	IM302	4
ENDRIN ALDEHYDE	0/21				1/30	0.63	2.84	IM307	0.63
ENDRIN KETONE	0/21				3/30	0.12 - 13	2.49	IM107	3.56
GAMMA-BHC (LINDANE)	0/21				2/30	0.14 - 0.19	1.41	IM410-MAX	0.19
GAMMA-CHLORDANE	0/21				4/30	0.067 - 13	1.60	IM711	2.02
HEPTACHLOR	0/21				2/30	0.061 - 1.2	1.47	IM307	1.2
HEPTACHLOR EPOXIDE	0/21				1/30	0.059	1.43	IM412	0.06
METHOXYCHLOR	0/21				1/30	0.81	13.62	IM410-MAX	0.81

Notes:
* - Minimum and maximum detected site-related concentrations are based on duplicate samples.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of all data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95% UCL, which is presented in a separate table.
Frequency of detection refers to the number of times compound was detected among all samples versus total number of samples.
Number of samples may vary based on the number of usable results.



No	DATE	REVISIONS	BY	CHKD.	APPD.	REFERENCES
1	4/19/00	SOIL BORING SAMPLE LOCATIONS REVISED, AND EXCAVATED AREAS ADDED.	LDL			

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CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS SCREENING CRITERIA EXCEEDANCES
AREA A – IMPOUNDMENT AREA
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Tra DATE 4/23/00
DRAWING NO. FIGURE 4-18
REV. 1

AREA-A_OU-6/7603gm27.dwg 2/28/00 EEH

AREA-A_OU-6/7603gm27.dwg

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4.6 COMPARISON OF SOIL CONCENTRATIONS TO OTHER SCREENING LEVELS

The exposure point concentrations (EPCs) for post-removal surface and subsurface soils associated with Area A were compared to the generic soil screening levels (SSLs) for the migration to groundwater pathway. The SSLs were selected based on a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface (EPA, 1996a). The SSLs assume that a receptor well is at the edge of a contaminated source, which implies that there is no dilution from recharge downgradient of the site being evaluated. In the case of Area A sites, there are no receptor wells within 1,000 feet of the site.

The purpose of the comparison was to identify and screen those hazardous substance concentrations in soil that might have the potential to contaminate groundwater. Table 4-18 shows the results of the comparison. If the EPC for a particular site and medium was greater than the SSL, the post-removal analytical database for that site and medium was evaluated to identify specific sample concentrations that were greater than the respective SSL. This approach does not necessarily identify all SSL exceedances for post-removal Area A soils because the EPC value for a specific contaminant may not be greater than the SSL. However, the EPC was assumed to be the most representative contaminant level at the soil-to-groundwater interface, after accounting for fate and transport processes that might attenuate, biodegrade, or otherwise retard the mobility of soil contaminants migrating through the unsaturated zone.

No soil-to-groundwater SSLs were exceeded for the post-removal Site 1 surface soil EPCs, and thallium was contained in one post-removal Site 3 surface soil sample (SS-03-02) slightly above the respective SSL. Among the Site 2 surface soil samples, chromium was detected in several samples above the SSL of 38 mg/kg. The maximum background level of chromium at the base was 35.3J mg/kg, which is near the SSL for this contaminant. The range of chromium detections varied from 39.4 to 116 mg/kg. No clear pattern of exceedances was observed. Only one organic compound was detected above its SSL; dieldrin was contained in sample SS-02-14. Figure 4-19 shows SSL exceedances for Site 2 post-removal surface soil samples. Site 3 post-removal surface soil SSL exceedances are detailed in Figure 4-20.

Figure 4-21 displays SSL exceedances for the Site 1 post-removal subsurface soil samples. No organic compound SSLs were exceeded for the post-removal Site 1 subsurface soil EPCs. Two inorganics, (cadmium and chromium) were contained in the Site 1 subsurface soil samples at EPC levels greater than the respective SSLs. Chromium was detected in all the samples that had at least one SSL exceedance for inorganics. Thallium (samples SB-01-20, SB-01-25, SB-01-66, and SB-01-69) and silver (sample SB-01-25) were also detected above their respective SSLs, however the EPCs for these substances did not exceed the SSLs.

TABLE 4-18
OCCURRENCE AND COMPARISON OF SOIL EPCs TO SOIL-TO-GROUNDWATER SOIL SCREENING LEVELS FOR AREA A SITES (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Substance	Maximum Soil Background Level	SSL	Site 1		Site 2		Site 3		Impoundment Area	Detected In On-Base Area A Groundwater (ug/l)
			Surface Soil	Subsurface Soil	Surface Soil	Subsurface Soil	Surface Soil	Subsurface Soil	Subsurface Soil	
ALUMINUM	18100		16,600	18,710	19,800	16,637	12,000	14,010	12,081	YES
ANTIMONY		5		3.60	3.8	11.47		9.67	19.10	NO
ARSENIC	12.1J	29		8.32	7.1	6.26	7.9	6.74	2.19	YES
BARIUM	225	1,600		130	224	121.0	99	419	107	YES
BERYLLIUM	1.7K	63		2.03	1.06	0.92	0.97	1.36	1.11	NO
CADMIUM		8		15.5	7.7	7.70		32.9	2.86	YES
CALCIUM	1910			5,468	42,064	9,426	27,905	22,175	5,540	YES
CHROMIUM	35.3JK	38	28	233	87.6	95.0	36.8	39.7	210	YES
COBALT	22.1		11.0	25.8	14.5	10.7	11	12.3	15.8	YES
COPPER	30.6			299	161	396.0	42.3	1,390	32.9	YES
CYANIDE		40		1.60		0.91	0.51		5.35	YES
HEXAVALENT CHROMIUM		38				0.0036			15.40	NO
IRON	410500		24,300	53,412	25,933	26,992	28,406	26,714	22,086	YES
LEAD	96.5J	400	11.8	31.3	152	230.0	28.69	1,016	17.9	YES
MAGNESIUM	4960			5,890	16,429	3,522	11,642	7,149	4,143	YES
MANGANESE	2,010		512	1,264	903	583	1,180	1,073	1,298	YES
MERCURY	0.37			0.46	0.57	0.14		8.2	0.10	YES
NICKEL	21.7J	130	12.8	28.6	20.7	18.7	20.79	44.7	19.0	YES
POTASSIUM	3050		892	4,600	1,679	948	2,464	1,407	1,897	YES
SELENIUM		5		1.29	0.61	0.54		0.68		NO
SILVER		34		17	23.3	12.40		368	5.9	YES
SODIUM	86.7			226	500	134.0	3,620	486	121	YES
THALLIUM		0.7		0.69	0.68	0.51	1.1	0.47	0.49	YES
VANADIUM	45	6,000	34.7	38.4	46	41.40	46.24	59	19.4	YES
ZINC	60	12,000		104	428	535.0	167	1,970	49.2	YES
CHLOROBENZENE		1,000	2					127		NO
OCDD						0.68		2.2		NO
OCDF						0.25				NO
1,1-DICHLOROETHANE		23,000				16				YES
1,2-DICHLOROETHENE (TOTAL)		400				22		4.00	11	YES
2-BUTANONE				4.8		24		128	23	YES
2-HEXANONE						2				NO
4-METHYL-2-PENTANONE				1.6		27.6			76	NO
ACETONE		16,000				109		140	523	YES
BENZENE		30	2			8		5.10		YES
BROMOMETHANE						17.1	21			NO
CARBON DISULFIDE		32,000				10		13.0		YES
CHLOROETHANE		1,000	2			3				NO
CHLOROFORM		600				4		1.00		YES
CHLOROMETHANE						17.8			2	YES
ETHYLBENZENE		13,000				13		130	14	YES
METHYLENE CHLORIDE		20				15.8		159		NO
1,1,2,2-TETRACHLOROETHANE		3					1		2	NO
TETRACHLOROETHENE		60				23			10	YES
TOLUENE	2J	12,000	2	2.9	2.00	26.2		120	8	YES
TRANS-1,3-DICHLOROPROPENE		4				25				NO
TRICHLOROETHENE		20				12			15	YES
XYLENES		200,000				20.7		220		YES
1,4-DICHLOROBENZENE	43J	2,000				68		120		NO
3,3-DICHLOROBENZIDINE		7				400				NO

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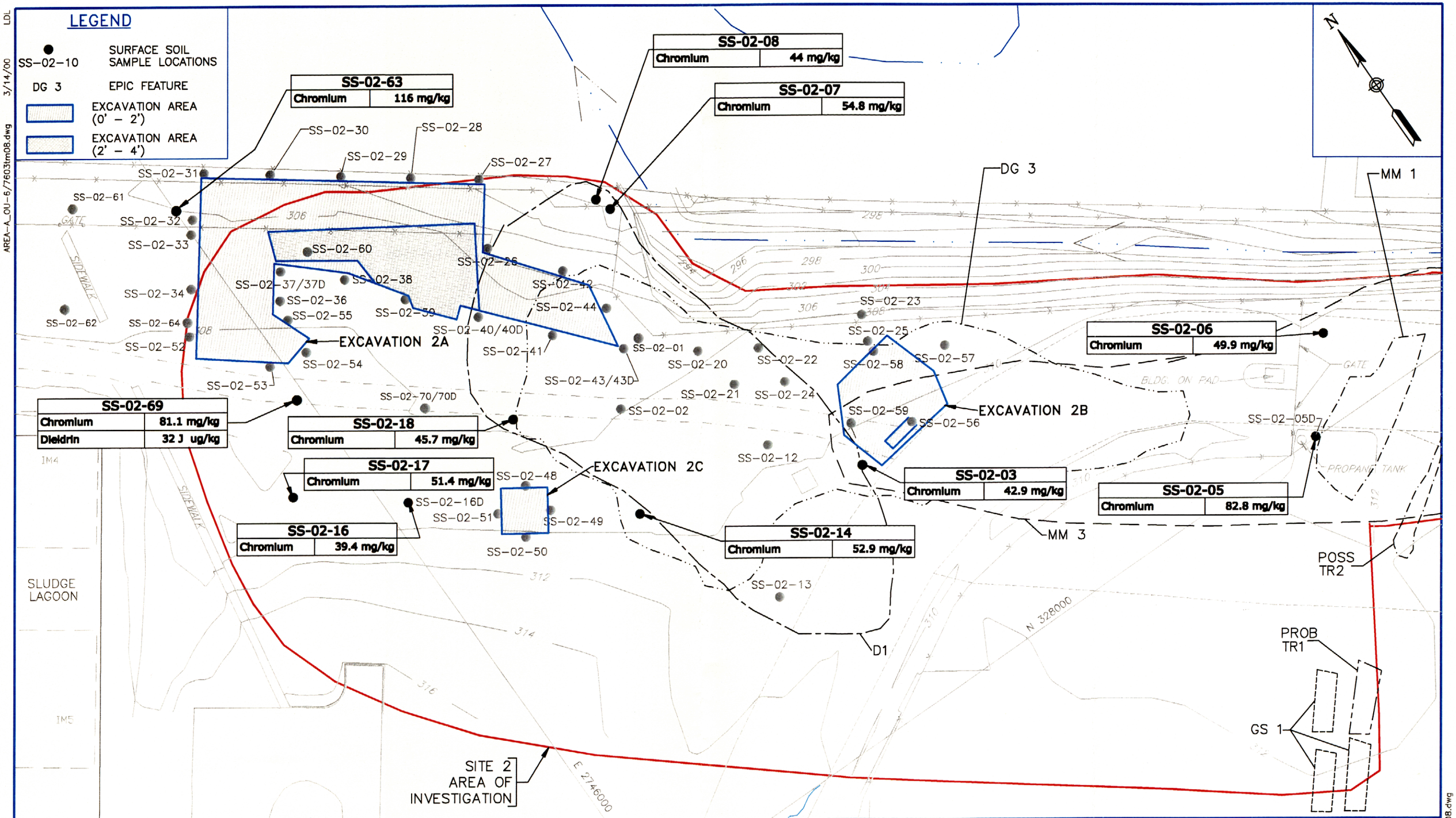
OCCURRENCE AND COMPARISON OF SOIL EPCs TO SOIL-TO-GROUNDWATER SOIL SCREENING LEVELS FOR AREA A SITES (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Substance	Maximum Soil Background Level	SSLs	Site 1		Site 2		Site 3		Impoundment Area	Detected in On-Base Area A Groundwater (ug/l)
			Surface Soil	Subsurface Soil	Surface Soil	Subsurface Soil	Surface Soil	Subsurface Soil	Subsurface Soil	
2-METHYLNAPHTHALENE					1,033	360		690	44	NO
4-METHYLPHENOL									160	NO
ACENAPHTHENE		570,000			180	471		3,646		NO
ACENAPHTHYLENE					440		120	1,200	299	NO
ANTHRACENE		12,000,000			640	528	220	21,000	297	NO
BENZO(A)ANTHRACENE		2,000			2,198	882	786	37,125	355	NO
BENZO(A)PYRENE		8,000			2,590	810	1,203	24,550	372	NO
BENZO(B)FLUORANTHENE	58J	5,000			4,841	941	947	35,976	386	NO
BENZO(G,H,I)PERYLENE					1,522	451	320	15,030	318	NO
BENZO(K)FLUORANTHENE	46J	49,000			1,756	546	1,000	32,962	288	NO
BIS(2-ETHYLHEXYL)PHTHALATE		3,600,000		40	1,800	700		4,000	285	NO
BUTYL BENZYL PHTHALATE		930,000				110		41		NO
CARBAZOLE		600			560	480		1,000		NO
CHRYSENE	51J	160,000			3,009	922	880.33	38,764	378	NO
DIBENZO(A,H)ANTHRACENE		2,000			470.0	417	99	8,291	34	NO
DIBENZOFURAN					73	417		300		NO
DIETHYL PHTHALATE		470,000				48		86		YES
DI-N-BUTYL PHTHALATE		2,300,000			61	651		53		NO
DI-N-OCTYL PHTHALATE		1,000,000						320		YES
FLUORANTHENE	92J	4,300,000			5,211	1,711	2,024	64,827	419	YES
FLUORENE		560,000			250	498	41	4,500	240	NO
HEXACHLOROETHANE		500						640		NO
INDENO(1,2,3-CD)PYRENE		14,000			1,717	636	380	10,710	321	NO
NAPHTHALENE		84,000			52	250		450		NO
PENTACHLOROPHENOL		30				62			120	NO
PHENANTHRENE	51J				2,742	1,181	1,100	36,617	311	YES
PHENOL		100,000						150		NO
PYRENE	100J	4,200,000			4,297	1,640	1,346	36,810	502	YES
4,4'-DDD	16JP	16,000		55	4.57	3.92		150	21.0	NO
4,4'-DDE		54,000		12.0	4.54	4.45		42	3.47	NO
4,4'-DDT	1440JP	32,000			10.3	6.16	15	26.1	7.56	NO
ALDRIN		500				1.42		123	1.65	NO
ALPHA-CHLORDANE		10,000			50.4	1.59			0.25	NO
AROCLOR-1242		1,000						58.7	31	NO
AROCLOR-1248		1,000				29.1		61.7		NO
AROCLOR-1254	51	1,000		27.1	596	37.5		597	33.2	NO
AROCLOR-1260		1,000			33.5	65.3		118	53.3	NO
DELTA-BHC						1.32			2.11	NO
DIELDRIN		4			9.05	2.87			5.32	NO
ENDOSULFAN I		18,000							0.8	NO
ENDOSULFAN II		18,000				2.34			4.36	NO
ENDOSULFAN SULFATE										NO
ENDRIN		1,000		4.80	123	4.46		15.7	4.00	NO
ENDRIN ALDEHYDE						2.9			0.63	NO
ENDRIN KETONE						2.75			3.56	NO
GAMMA-BHC (LINDANE)		9			4.84	1.39	2.48	3.5	0.19	NO
GAMMA-CHLORDANE		10,000			4.98	1.5		9.68	2.02	NO
HEPTACHLOR		23,000							1.2	NO
HEPTACHLOR EPOXIDE		700				1.42		5.81	0.06	NO
METHOXYCHLOR		160,000							0.81	NO

Notes:
* - Exposure point concentrations (EPCs).
Units are mg/kg for inorganics, ug/kg for organics.
Shaded blocks indicate EPC values > SSL and > maximum soil background level.
Reference: EPA, Soil Screening Technical Guidance Document, Appendix A, Table A-1 (assuming DAF = 20). May 1996.
References: RI Report for OU-1 Groundwater, Halliburton NUS. April 1993. Summary Report for Area A and D Groundwater, Brown & Root Environmental. December 1997.
Summary Report for Round 12 Perimeter Groundwater Monitoring, Tetra Tech NUS. September 1999



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CHECKED BY DATE			OWNER NO. 0601
REVISED BY DATE			APPROVED BY Tea DATE 4/23/00
SCALE AS NOTED			DRAWING NO. FIGURE 4-19 REV.

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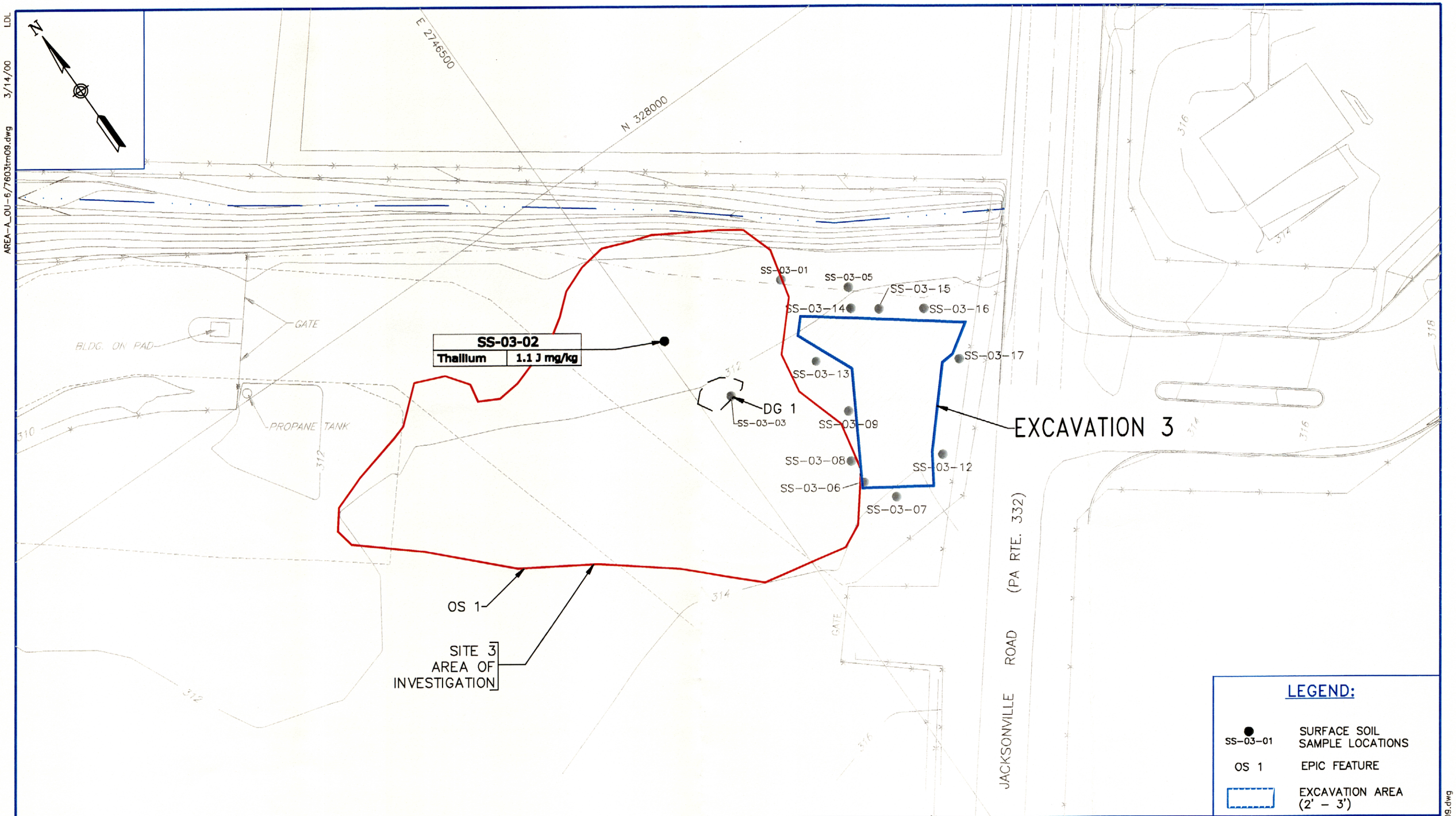

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CHECKED BY DATE			OWNER NO. 0601
REVISED BY DATE			APPROVED BY Tea DATE 4/23/00
SCALE AS NOTED			DRAWING NO. FIGURE 4-20 REV.

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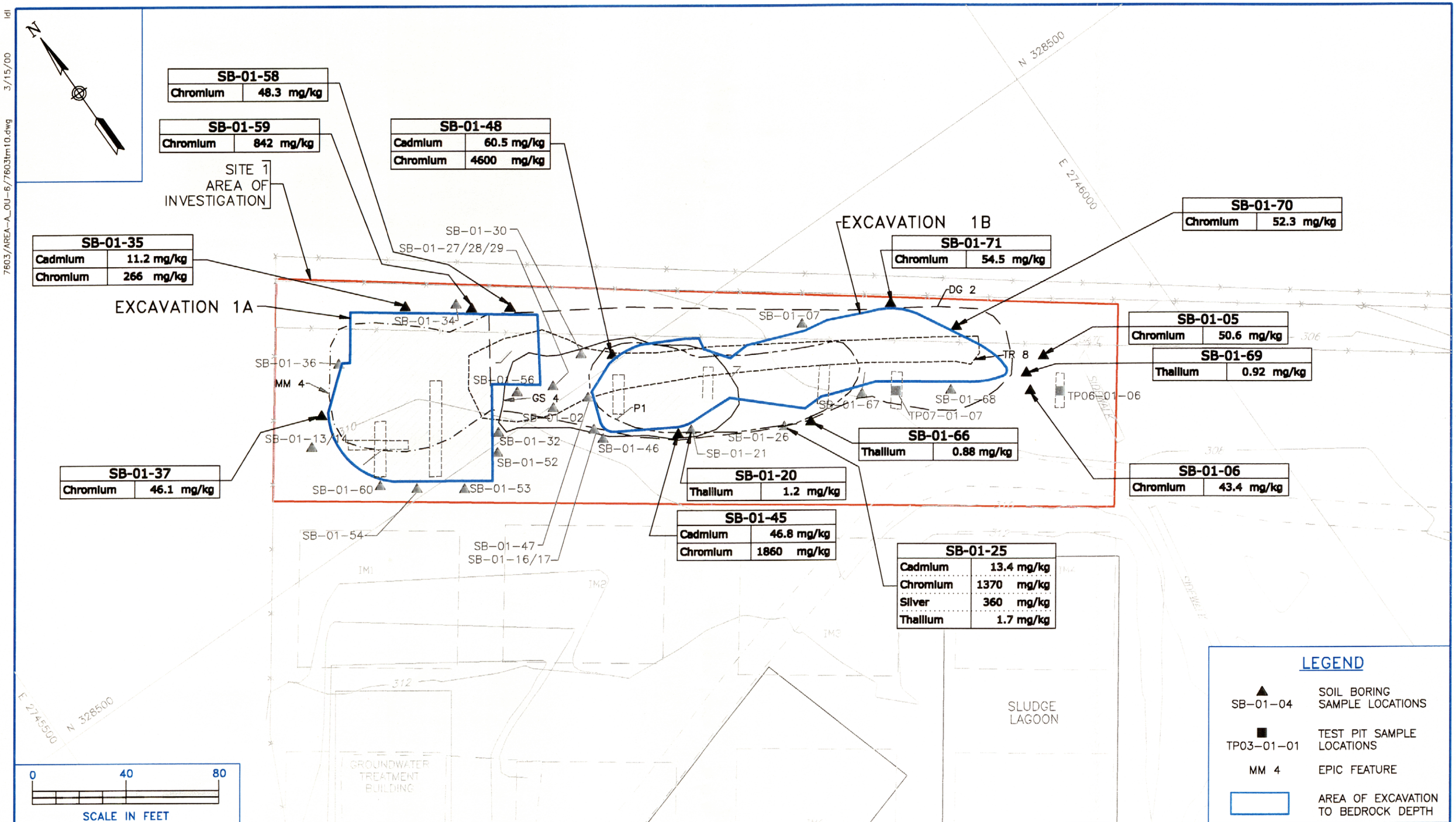

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CHECKED BY DATE
REVISED BY DATE
SCALE AS NOTED

Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SSL EXCEEDANCES
AREA A – SITE 1
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY Tea DATE 4/23/00
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REV. 1

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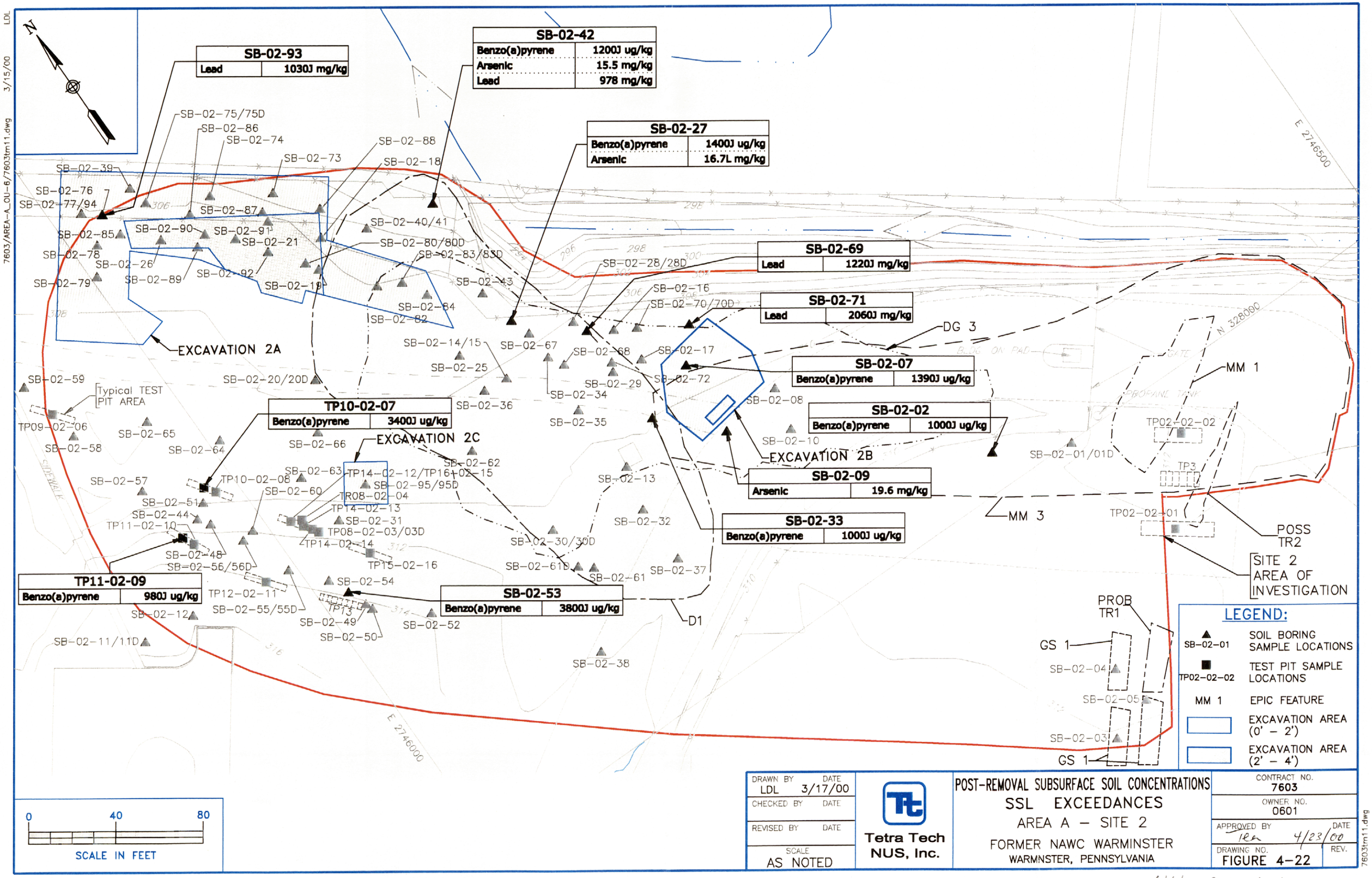
In general, only inorganics were contained in the post-removal Site 2 subsurface soil samples at levels greater than the SSLs, as detailed in Figure 4-22. The SSLs for cadmium and chromium were most frequently exceeded, and, to a lesser extent, antimony. Antimony has not been found in on-base Area A groundwater samples to date. Among organic compounds, only pentachlorophenol (sample SB-02-08) and 3,3-dichlorobenzidine (sample SB-02-07) were detected above their SSLs. These compounds have not been contained in on-base Area A groundwater samples.

For the post-removal Site 3 subsurface soil samples, antimony, cadmium, chromium, lead, and, less frequently, silver were found in one or more samples above the SSLs (see Figure 4-23). Similar to Site 1 subsurface soil, chromium was detected in most samples that contained at least one inorganic concentration above an SSL. Benzo(a)anthracene was found in five samples above its SSL, with concentrations ranging from 2,500J to 53,000 ug/kg. Methylene chloride, carbazole, benzo(a)pyrene, dibenz(a,h)anthracene, and hexachloroethane were each contained in only one Site 3 subsurface soil sample at levels greater than their respective SSLs, and benzo(b)fluoranthene was detected in two samples. Sample SB-03-18 contained the highest PAH concentrations in every instance, including the maximum benzo(a)anthracene concentration. The PAHs of concern have not been found in Area A groundwater. Aroclor-1254 was detected in sample SB-03-21 above its SSL; however, the EPC for Aroclor 1254 was not exceeded for Site 3 subsurface soil.

Concerning the Impoundment Area, chromium and, less often, antimony were the most frequent contaminants detected above their SSLs (see Figure 4-24). The highest levels of chromium (3,760 and 4,730 mg/kg) and antimony (57.8 and 144J mg/kg) were found in samples collected at the former locations of Impoundment Nos. 1 and 7. The other inorganic detected above its SSL at the Impoundment Area was lead in sample IM8-02. Only two organic compounds, dieldrin and pentachlorophenol, were contained in the Impoundment Area subsurface soil sample (samples IM1-07 and IM7-11) above the SSLs.

The soil removal actions at Area A have helped to minimize the future release of contaminants through soil leaching and the transport of contaminants through soil and groundwater to nearby receptor wells. The small size of the sites being evaluated and the presence of relatively impenetrable surfaces (e.g., parking lots, paved roads, concrete-lined impoundments) upgradient and near the sites greatly reduce the amount of infiltration available to transport substances through the subsurface. In addition, the SSL methodology does not consider physical and chemical processes that might attenuate contaminants in subsurface soils. As such, the results of the comparison between SSLs and soil EPCs should be viewed as a conservative and simple evaluation of the potential for soil contaminants to significantly affect



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Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SSL EXCEEDANCES
AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY [illegible] DATE 4/23/00
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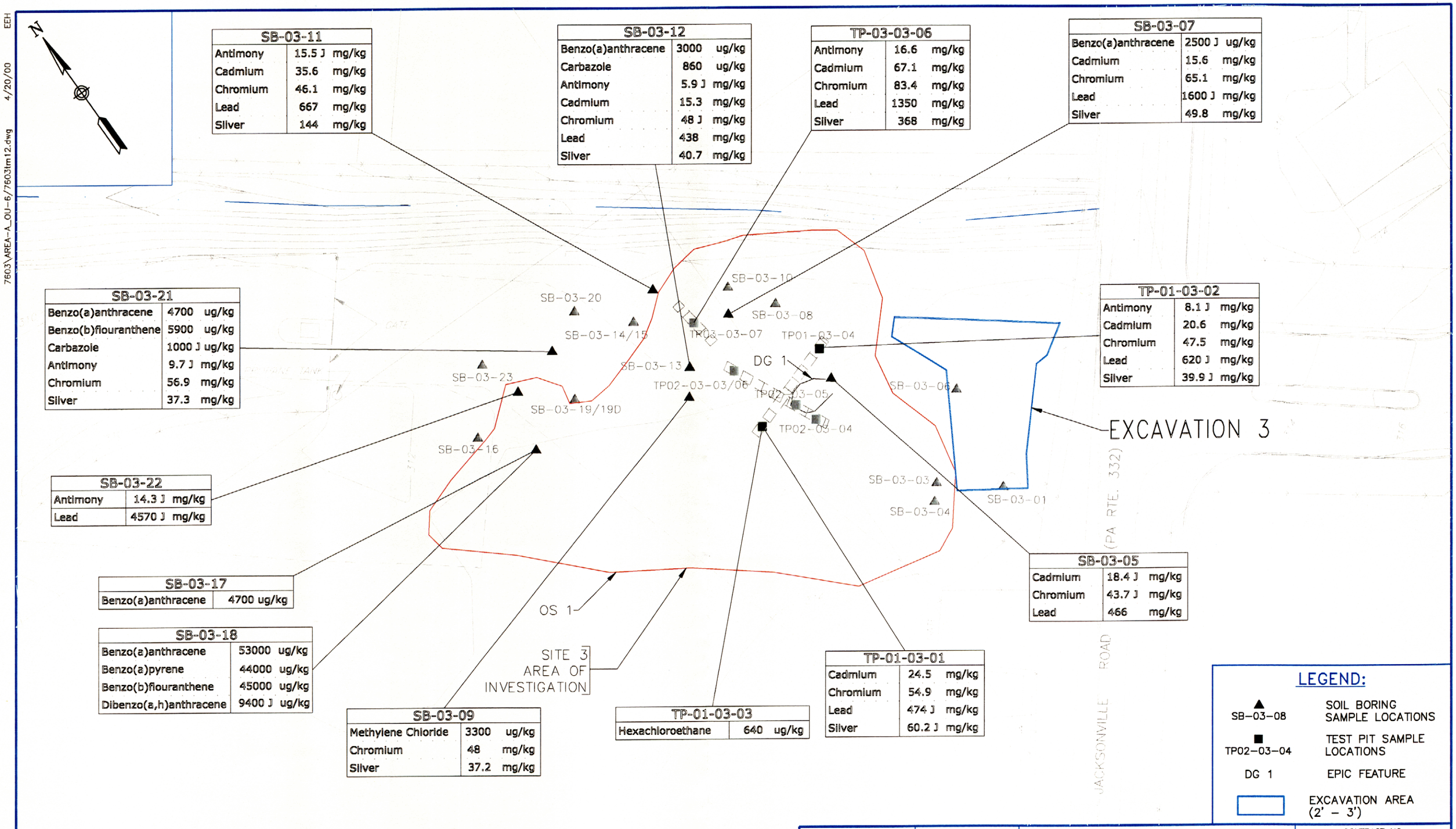

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Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SSL EXCEEDANCES
AREA A – SITE 3
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
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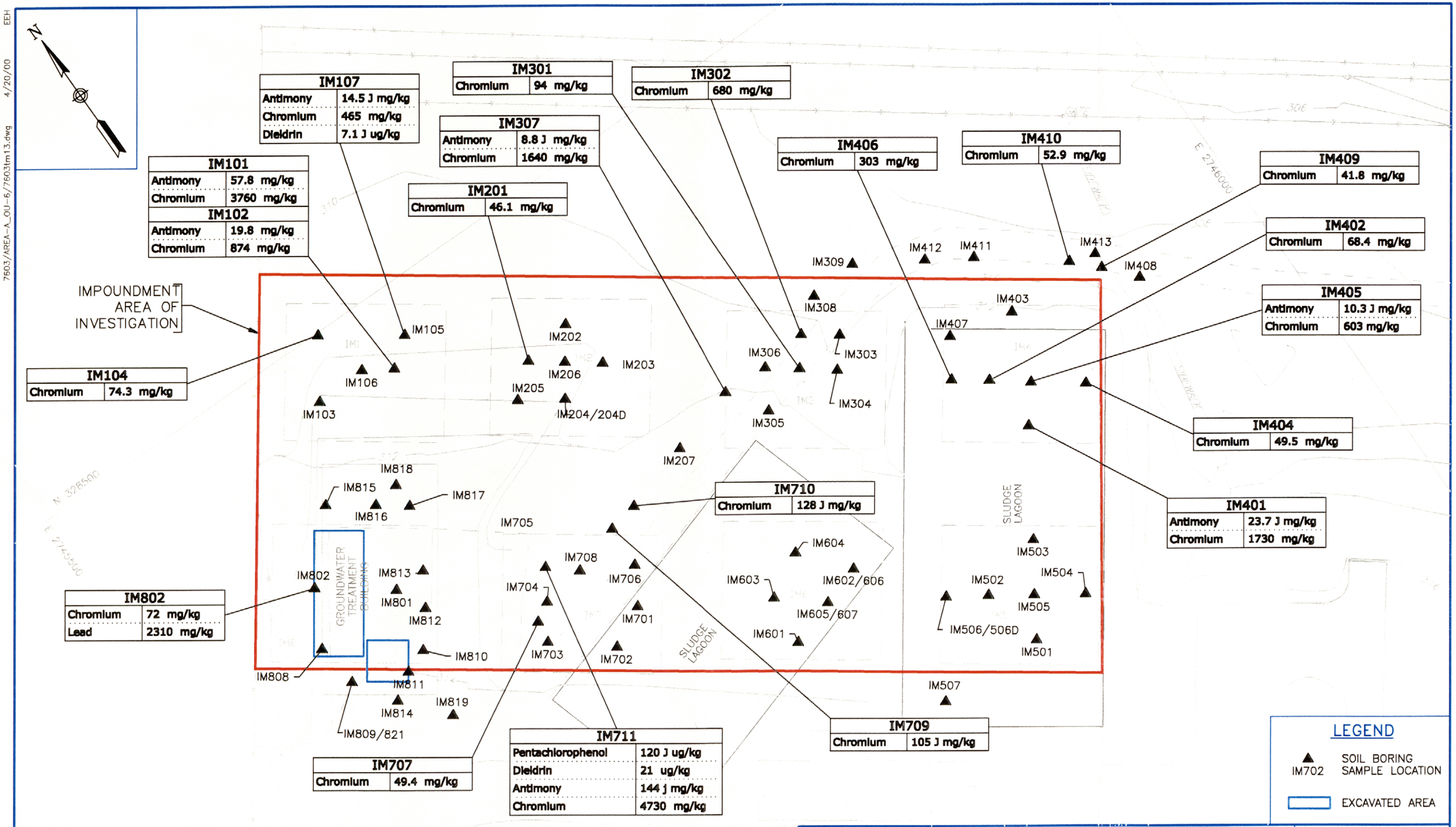

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Tetra Tech NUS, Inc.

POST-REMOVAL SUBSURFACE SOIL CONCENTRATIONS
SSL EXCEEDANCES
AREA A – IMPOUNDMENT AREA
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY DATE 4/23/00
DRAWING NO. FIGURE 4-24
REV.

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groundwater quality. In addition, the ongoing pumping and treating of Area A groundwater for both organic and inorganic hazardous substances have a notable influence on controlling and preventing the widespread release of contaminants in the subsurface.

4.7 SURFACE WATER

The Area A surface water sample locations are shown on Figures 2-3 and 2-4. During Phase I and Phase II, two surface water samples were collected from the unnamed tributary north of Area A; the Phase II surface water samples were collected in approximately the same locations as the samples in Phase I. During Phase III, samples from 14 site-related surface water locations (A1 through A12, A16, A19, A20, and A22 including duplicates) were collected during two rounds of sampling. The designated background surface water samples (samples C8-SW, C10-SW, and C13-SW) were collected east of Area A (specifically Site 3) along a tributary of Little Neshaminy Creek. An additional background sample (sample A13-SW) was collected northwest of Area A along the tributary. These four background samples are in the same watershed as Area A (both tributaries empty into Little Neshaminy Creek) and showed lower concentrations of chemicals than other samples collected in the vicinity of Area A. Additionally, these samples were collected in a relatively non-urban area and are considered to be representative of undisturbed surface water and sediment for Area A. All other samples collected near Area A are considered to be potentially impacted by Area A, with sample A11-SW considered the farthest downstream surface water sample.

No organic chemicals were detected in the surface water background samples. The Area A site related surface water results are shown in Appendix A. Analytical data from the Area A background samples is contained in Appendix G. Several VOCs were detected in six site-related samples (samples A4-SW through A8-SW and A29-SW). As shown on Figure 2-3, sample locations A6 through A8 are considered downstream of all known or potential sites within Area A and samples A4 and A5 are considered downstream of Sites 2 and 3 only. Location A29 is downstream of Site 3 only. The six samples all had at least one detected VOC. Chloromethane (4J ug/l) and carbon disulfide (6J ug/l) were detected in samples A6-SW and A7-SW, respectively. Chloroethane was detected at 3J ug/l in sample A6-SW. TCE was detected at levels ranging from 1J ug/l to 2J ug/l in samples A6-SW, A7-SW, and A8-SW. PCE (1J ug/l) and 2-butanone (4J ug/l) were also detected in sample A8-SW. Three VOCs, bromomethane, 1,1-DCA, and benzene, were detected in sample A29-SW, collected during a 1991 sampling event. The levels of these three VOCs ranged from 0.2J to 0.95J ug/l.

Seven semivolatile organic compounds, including phthalates and PAHs, were detected in surface water samples A28-SW and A29-SW. As shown on Figure 2-3, sample location A28-SW was located downstream of Area A. Sample A28-SW had PAH concentrations ranging from 0.1J to 0.3J ug/l,

including fluoranthene, pyrene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene. Two phthalates, diethyl- and di-n-octyl-, were also found in sample A28-SW in the same concentration range. Sample A29-SW, located downstream of Site 3 only, showed the presence of only one PAH, di-n-octyl phthalate, at a concentration of 0.2J ug/l.

No pesticides or PCBs were detected in the Area A surface water samples, with the exception of sample A12-SW. This sample was collected from a far downstream location (see Figure 2-4) and contained 0.0092J ug/l of 4,4'-DDD and 0.014J ug/l of 4,4'-DDT. Table 4-19 presents the occurrence and distribution of organic compounds in surface water samples from Area A.

Generally, low levels of metals were detected in the Area A background surface water samples. Total metal concentrations for barium (69.7 ug/l), cadmium (4 ug/l), and manganese (83 ug/l) were detected in the background samples. Dissolved metal concentrations for barium (74.5 ug/l), copper (14.8L ug/l), and manganese (73 ug/l) were also found in at least one background surface water sample. Higher concentrations of metals were detected in other Area A samples. Dissolved metal concentrations for barium (ranging from 65.6 to 146ug/l), copper (5.4J to 21.8K ug/l), and manganese (9.6J to 435 ug/l) were detected in most site-related surface water samples. Arsenic was detected in two site-related surface water samples, samples A2-SW-F and A6-SW-F, at concentrations of 2.1 and 2.3 ug/l, respectively. The highest total metal concentrations were detected in surface water samples A6 and 2A. Surface water sample A29-SW was collected from a location close to Jacksonville Road, and both thallium (2 ug/l) and chromium (4 ug/l) were detected at this November 1991 sample location. Thallium and chromium were not detected in any other Area A surface water samples collected since 1991. The Area A dissolved metal concentrations were generally lower than total metal concentrations.

Figure 4-25 details Area A surface water sample results that exceed current Ambient Water Quality Criteria (AWQC), as discussed in Section 2.0. Fourteen samples had barium concentrations that exceeded the established criteria. The barium exceedances ranged from 59.5 ug/l to 147 ug/l. The criterion for manganese was exceeded in 11 samples, and the lead criterion was exceeded in five samples. Manganese exceedances ranged from 92.2 ug/l to 486 ug/l in a sample from location A6. Surface water samples from locations A6 and A31 had the most compounds with exceedances of the AWQC.

Comparison of the site-related surface water results to background reveals that, with the exception of cadmium, the background results were generally lower. Lead concentrations ranging from 2.9J to 28.5 ug/l and copper concentrations ranging from 101 to 106 ug/l were also detected in the site-related samples. Sample A6-SW generally had the highest levels of detected metals. Some analytes, such as

TAB 19

OCCURRENCE AND DISTRIBUTION OF ORGANICS IN SURFACE WATER AT AREA A

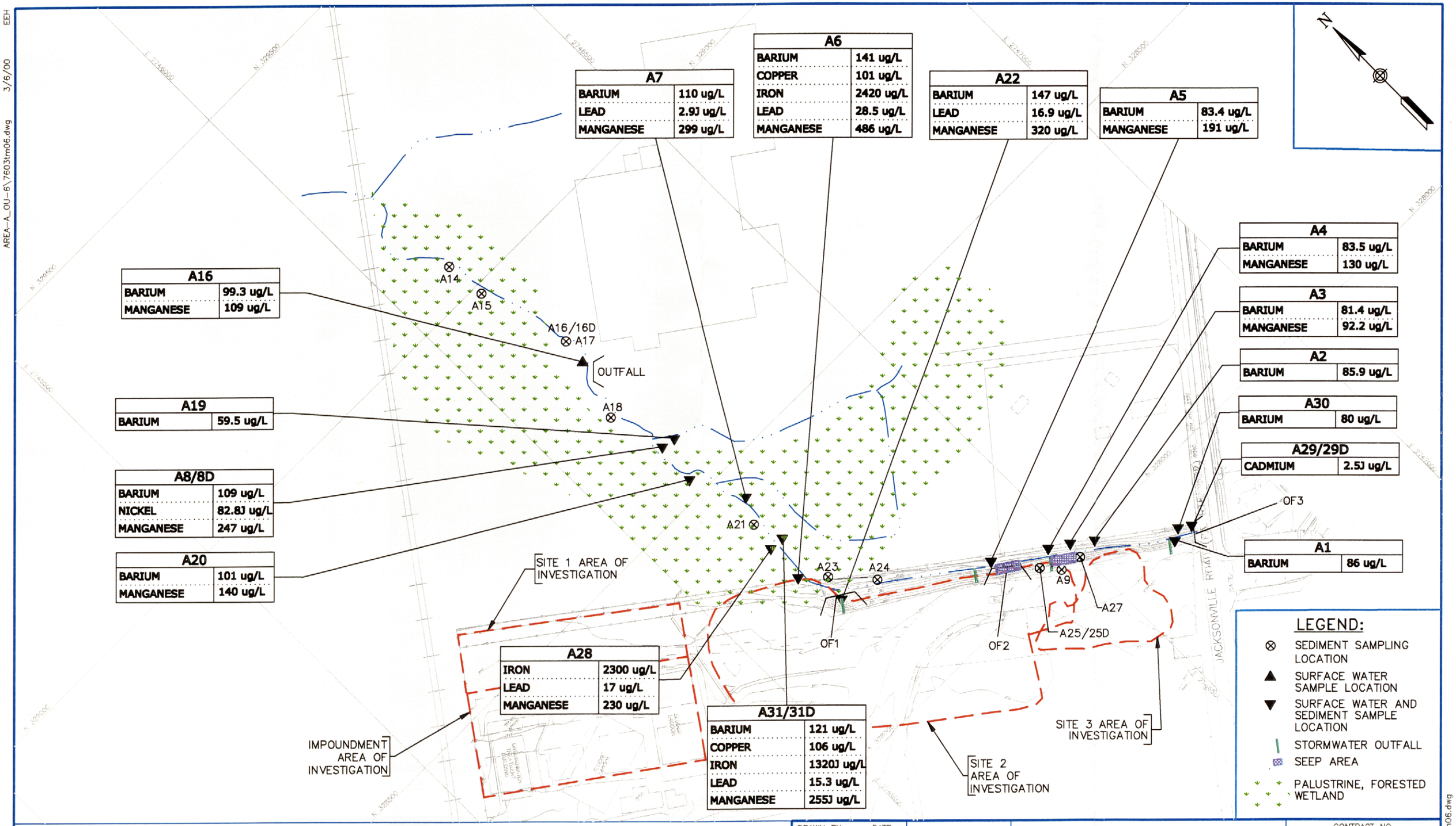
NAWC WARMINSTER, PENNSYLVANIA

(ug/L)

SUBSTANCE	BACKGROUND	SITE-RELATED			
	REPRESENTATIVE CONCENTRATION*	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	STATISTICAL DISTRIBUTION	REPRESENTATIVE CONCENTRATION
4,4'-DDD	-	1 / 9	0.0092	LOGNORMAL OVER NORMAL	0.0092
4,4'-DDT	-	1 / 7	0.014	LOGNORMAL OVER NORMAL	0.014
BENZO(A)ANTHRACENE	-	1 / 8	0.1	LOGNORMAL OVER NORMAL	0.1
BENZO(B)FLUORANTHENE	-	1 / 8	0.2	LOGNORMAL OVER NORMAL	0.2
CHRYSENE	-	1 / 8	0.2	LOGNORMAL OVER NORMAL	0.2
DI-N-OCTYLPHTHALATE	-	2 / 6	0.1 - 0.2	NORMAL OVER LOGNORMAL	0.2
DIETHYLPHTHALATE	-	1 / 6	0.2	LOGNORMAL OVER NORMAL	0.2
FLUORANTHENE	-	1 / 8	0.3	LOGNORMAL OVER NORMAL	0.3
PYRENE	-	1 / 8	0.3	LOGNORMAL OVER NORMAL	0.3
1,1-DICHLOROETHANE	-	1 / 13	0.95	LOGNORMAL OVER NORMAL	0.95
2-BUTANONE	-	1 / 11	4	LOGNORMAL OVER NORMAL	4
BENZENE	-	1 / 13	0.2	LOGNORMAL OVER NORMAL	0.2
BROMOMETHANE	-	1 / 13	0.5	LOGNORMAL OVER NORMAL	0.5
CARBON DISULFIDE	-	1 / 13	6	LOGNORMAL OVER NORMAL	5.48
CHLOROETHANE	-	1 / 13	3	LOGNORMAL OVER NORMAL	3
CHLOROMETHANE	-	1 / 13	4	LOGNORMAL OVER NORMAL	4
TETRACHLOROETHENE	-	1 / 13	1	LOGNORMAL OVER NORMAL	1
TRICHLOROETHENE	-	3 / 13	1 - 2	NORMAL OVER LOGNORMAL	2

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES



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Tetra Tech NUS, Inc.

SURFACE WATER CONCENTRATIONS
SCREENING CRITERIA EXCEEDANCES
AREA A
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
OWNER NO. 0601
APPROVED BY RPA DATE 4/23/00
DRAWING NO. FIGURE 4-25
REV.

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442 B29Y

beryllium, mercury, selenium, silver, and vanadium, were not detected in the Area A surface water samples.

Sample A22-SW, taken from within Outfall No. 1, contained total metal concentrations of barium (147 ug/l), lead (16.9 ug/l), manganese (320 ug/l), and zinc (31.3J ug/l) that were greater than background levels. Comparison of the sample A22-SW results to results from sample A20-SW, which was taken downstream, shows that the downstream results were lower. Surface water results from sample A19-SW, located at the confluence of unnamed streams south of the Wagner & Sons property and downstream of sample A20-SW, showed no elevated total metal concentrations. This indicates that elevated total metal concentrations downstream of Area A are probably not related to off-base properties and are perhaps associated with the discharge from Outfall No. 1. Tables 4-20 and 4-21 present the occurrence and distribution of total and dissolved inorganics in background and other Area A surface water samples.

4.8 SEDIMENT RESULTS

Sediment sample locations within Area A are shown on Figures 2-3 and 2-4. During Phase I, two sediment samples (A28-SD and A29-SD) were collected. Two sediment samples (A31-SD and A30-SD) were collected during Phase II at approximately the same locations as the Phase I samples. During Phase III, sediment samples were collected from 23 locations (A1 through A27, including duplicates) in the vicinity of Area A. Similar to the surface water samples, the designated background sediment samples (C8-SD, C10-SD, and C13-SD) were collected east of Area A along a tributary of Little Neshaminy Creek (see Figure 2-3). A far downstream background sample was also collected from location A13 (see Figure 2-4). All other collected samples were considered to be potentially impacted by Area A. The Area A sediment results are shown in Appendix A for VOCs, semivolatile organics, pesticides/PCBs, and inorganics. Analytical data from the Area A background sediment samples are contained in Appendix G.

No VOCs, pesticides, or PCBs were found in the background sediment samples collected from the nearby locations (C10 and C13). The sample from location C8 was not analyzed for pesticides and PCBs but was analyzed for VOCs. No VOCs were detected in background sample C8-SD. 2-Butanone and toluene were detected at 9.0J ug/kg and 4.0 ug/kg, respectively, in sample A13-SD. The far downstream background sample also contained 4,4'-DDT at 4.9J ug/kg, endrin at 5.5J ug/kg, and Aroclor 1254 at 24.0J ug/kg.

A number of VOCs were detected in the Area A sediment samples. Sediment samples A7-SD and A28-SD had the most frequent VOC detections with five and six hits, respectively. Seven locations each had two VOCs detected, while samples from ten locations had only one detected VOC each. TCE and PCE

TABLE 4-20

OCCURRENCE AND DISTRIBUTION OF TOTAL INORGANICS IN SURFACE WATER AT AREA A

NAWC WARMINSTER, PENNSYLVANIA

(ug/L)

	BACKGROUND	SITE-RELATED			
SUBSTANCE	REPRESENTATIVE CONCENTRATION*	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	STATISTICAL DISTRIBUTION	REPRESENTATIVE CONCENTRATION
ALUMINUM	106	1 / 5	116	NONPARAMETRIC DIST	116
BARIUM	69.7	16 / 18	59.5 - 172	NORMAL	142.56
CADMIUM	4	1 / 16	2.5	NORMAL OVER LOGNORMAL	1.54
CALCIUM	19400	16 / 16	11100 - 64300	NONPARAMETRIC DIST	39279
CHROMIUM	-	1 / 14	4	LOGNORMAL OVER NORMAL	3.26
COPPER	-	4 / 8	5.6 - 106	NORMAL	64.71
IRON	690	9 / 9	69 - 2420	NONPARAMETRIC DIST	2420
LEAD	-	5 / 15	2.9 - 28.5	NORMAL OVER LOGNORMAL	9.89
MAGNESIUM	7240	16 / 16	4470 - 23900	NONPARAMETRIC DIST	16015
MANGANESE	83	15 / 18	15.1 - 486	NONPARAMETRIC DIST	382.34
NICKEL	-	3 / 18	12.5 - 82.75	NORMAL OVER LOGNORMAL	18.57
POTASSIUM	1700	12 / 12	1150 - 5380	NORMAL OVER LOGNORMAL	2434
SODIUM	16200	16 / 16	8020 - 58900	NORMAL	30262
THALLIUM	-	1 / 15	2	LOGNORMAL OVER NORMAL	1.58
ZINC	-	14 / 15	20.8 - 117	NORMAL OVER LOGNORMAL	55.62

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

TAL 21

OCCURRENCE AND DISTRIBUTION OF DISSOLVED INORGANICS IN SURFACE WATER AT AREA A

NAWC WARMINSTER, PENNSYLVANIA

(ug/L)

SUBSTANCE	BACKGROUND REPRESENTATIVE CONCENTRATION*	SITE-RELATED FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	STATISTICAL DISTRIBUTION	REPRESENTATIVE CONCENTRATION
ANTIMONY	-	1 / 16	100	NORMAL OVER LOGNORMAL	34.48
ARSENIC	-	2 / 15	2.1 - 2.3	LOGNORMAL OVER NORMAL	1.33
BARIUM	74.5	16 / 16	65.6 - 146	NONPARAMETRIC DIST	107.23
CADMIUM	-	1 / 16	2.2	NORMAL OVER LOGNORMAL	1.53
CALCIUM	22100	16 / 16	20700 - 49700	NONPARAMETRIC DIST	37020
CHROMIUM	-	2 / 11	7.5 - 13.6	NORMAL OVER LOGNORMAL	6.18
COPPER	14.8	14 / 15	5.4 - 21.8	LOGNORMAL	21.8
IRON	-	7 / 8	60.6 - 293	LOGNORMAL	293
LEAD	1	2 / 15	3.9 - 19.9	NORMAL OVER LOGNORMAL	4.36
MAGNESIUM	7920	16 / 16	8350 - 20300	NONPARAMETRIC DIST	14679
MANGANESE	73	15 / 15	9.6 - 435	NONPARAMETRIC DIST	435
NICKEL	-	2 / 16	7.2 - 8.5	LOGNORMAL OVER NORMAL	7.32
POTASSIUM	1470	16 / 16	1150 - 2350	NONPARAMETRIC DIST	1846
SODIUM	18400	16 / 16	7990 - 55100	NONPARAMETRIC DIST	31842
ZINC	11	7 / 7	5.6 - 72	NONPARAMETRIC DIST	72

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

were the most frequently detected VOC compounds. TCE was detected in eleven sediment samples at concentrations ranging from 2J to 1300 ug/kg. PCE was detected in ten samples at concentrations ranging from 2J to 130 ug/kg. The highest concentration of TCE (1,300 ug/kg) was found in sample A20-SD and elevated levels were also found in samples A7-SD (69.0 ug/kg) and A8-SD (19.0 ug/kg), collected from locations on either side of sample A20-SD. The maximum concentration of PCE was detected in sample A7-SD. Samples A20-SD and A8-SD also contained PCE at 98.0 ug/kg and 16.0 ug/kg, respectively. The three sample locations are downstream of Area A and outfall OF1.

1,2-Dichloroethene (total) and 2-butanone were detected in five and three sediment samples, respectively. Concentrations of 1,2-dichloroethene ranged from 2.0J to 22.0 ug/kg. Samples A20-SD and A7-SD had the most elevated concentrations, 22.0 ug/kg and 15.0 ug/kg, respectively. 2-Butanone was detected in samples A11-SD, A12-SD, and A23-SD at concentrations ranging from 3.0J ug/kg (A12-SD) to 45.0J ug/kg (A23-SD). Chloroform was detected in two samples, A29-SD at 14.8J ug/kg and A20-SD at 4.0J ug/kg. The remaining VOCs were detected only in one sample each and included 1,1-dichloroethene, acetone, carbon tetrachloride, chloromethane, ethylbenzene, toluene, 1,1,1-trichloroethane, and xylene.

Some pesticides were detected in sediment samples A30-SD, A1-SD, A4-SD, and A7-SD, and PCBs were found in samples A28-SD and A7-SD. Two pesticides, 4,4'-DDT (13 ug/kg) and endrin aldehyde (30J ug/kg), were detected in sample A1-SD. 4,4'-DDD (11.0 ug/kg) and 4,4'-DDT (50.0 ug/kg) were also found in sample A30-SD, and 4,4'-DDE (7.0J ug/kg) and 4,4'-DDT (8.6 ug/kg) were detected in samples A7-SD and A4-SD, respectively. 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were found frequently in samples A11-SD through A27-SD. The highest concentration of 4,4'-DDT (600 ug/kg) was found at A14-SD. A12-SD, A20-SD, A25-SD, and A27-SD also had elevated levels of 4,4'-DDT. A19-SD (56.0J ug/kg) and A25-SD (36.0J ug/kg) also had elevated levels of 4,4'-DDD. The most frequently detected PCB was Aroclor 1254, detected in 16 of the 23 site-related sediment samples. Aroclor 1254 was found in A25-SD (950J ug/kg) and A26-SD (280 ug/kg) at elevated levels. High levels were also observed in A14-SD, A15-SD, A18-SD, A19-SD, and A22-SD. Aroclors 1248 and 1260 were both detected in sample A28-SD at concentrations of 1,500L ug/kg. Aroclors 1016 and 1260 were found in sample A7-SD at concentrations of 110J and 610J ug/kg, respectively.

Several semivolatile organics, including PAHs or phthalates, were detected in all Area A sediment samples. Background sample 3A detected four PAHs with concentrations ranging from 190J to 380J ug/kg. Background sample 3B also contained PAH concentrations ranging from 53.0J to 590 ug/kg. No phthalates were detected in the nearby background samples. Di-n-butyl phtalate was detected at 59.0 J ug/kg in far downstream background sample A13-SD. PAH concentrations in sample A13-SD ranged from 47.0J to 1400 ug/kg.

Samples A28-SD, A31-SD, A29-SD, A1-SD, A7-SD, A16-SD, A22-SD, A23-SD, and A24-SD had the highest semivolatile organic detections. Each sample contained at least one SVOC at a concentration greater than 10,000 ug/kg. Sediment sample A29-SD contained three phthalates, butylbenzyl-, di-n-octyl-, and bis(2-ethylhexyl)-, at concentrations ranging from 110J to 7,900J ug/kg. Two phthalates, bis(2-ethylhexyl)- and butylbenzyl-, were detected in other samples at levels ranging from 41J to 6,600 ug/kg. Some PAHs were also detected in sample 2A with levels ranging from 60J to 10,600 ug/kg. No phthalates were found in sediment sample A1-SD; however, PAH concentrations ranged from 860J to 43,000 ug/kg. In other samples, PAH concentrations ranged from 44J to 38,000 ug/kg. The sample results for A28-SD, A31-SD, and A7-SD were generally 50 to 100 times higher than background concentrations; sample A7-SD generally had the highest PAH concentrations. In sample A7-SD, PAH levels ranged from 2,400J to 38,000 ug/kg. The PAH concentrations in sample A29-SD were generally five to 10 times higher than PAH concentrations in samples A30-SD and A4-SD which, in turn, were slightly higher than background levels. Sample A-16-SD had hits of PAH levels ranging from 1,000J to 17,000J ug/kg; sample A22-SD had PAHs ranging from 1,300J to 27,000J ug/kg; and sample A27-SD showed PAHs ranging from 940J to 9,900J ug/kg. Table 4-22 presents the occurrence and distribution of organics in Area A sediment samples.

Table 4-23 presents the occurrence and distribution of inorganics in Area A sediment samples. Inorganics were detected in all sediment samples. Arsenic, beryllium, chromium, cobalt, lead, manganese, nickel, vanadium, and zinc were found in background samples. The other Area A sediment samples contained these metals, along with cadmium, mercury, selenium, and silver. These samples generally contained higher concentrations of beryllium, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc than the background sediment samples. Samples A3-SD, A5-SD through A9-SD, A28-SD, and A31-SD generally contained higher metal concentrations than samples A2-SD, A4-SD, A22-SD, A25-SD, and A26-SD. Maximum metal concentrations included arsenic (14.3 ug/kg), barium (1,060J ug/kg), beryllium (2.1 ug/kg), chromium (224J ug/kg), copper (136 ug/kg), lead (404 ug/kg), mercury (2.5 ug/kg), selenium (1.9J ug/kg), silver (2J ug/kg), and zinc (8,490 ug/kg).

Figure 4-26 details Area A sediment sample results that exceeded the ER-L screening criteria. Samples from locations A25 and A27 located adjacent to Sites 2 and 3 had exceedances of 19 and 20 compounds, respectively. Sediment sample location A22, collected at the OF1 outfall, exceeded the screening criteria of 20 compounds. Downstream sample locations with a high number of exceedances were A23, A28, A7, and A16, as detailed on Figure 4-19. The compounds most frequently exceeded included PAHs, 4,4'-DDT, Aroclor 1254 and 1260, arsenic, copper, lead, mercury, and zinc.

In general, the highest metal concentrations were from samples from locations A6 through A8 and A31,

OCCURRENCE AND DISTRIBUTION OF (SEDIMENT AT AREA A
NAWC WARMINSTER, YLVANIA
(ug/kg)

SUBSTANCE	BACKGROUND REPRESENTATIVE CONCENTRATION*	SITE-RELATED FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	STATISTICAL DISTRIBUTION	REPRESENTATIVE CONCENTRATION
4,4'-DDD	-	15 / 20	5 - 130	NORMAL OVER LOGNORMAL	31.80
4,4'-DDE	-	2 / 21	7 - 13	NORMAL OVER LOGNORMAL	13
4,4'-DDT	4.9	15 / 18	8.6 - 600	NORMAL	116.95
ALDRIN	-	5 / 21	2.1 - 78.5	NORMAL OVER LOGNORMAL	14.04
ALPHA-CHLORDANE	-	2 / 19	2.2 - 2.7	NORMAL OVER LOGNORMAL	2.7
AROCLOR-1016	-	1 / 21	110	NORMAL OVER LOGNORMAL	86.72
AROCLOR-1248	-	1 / 21	1500	NORMAL OVER LOGNORMAL	231.07
AROCLOR-1254	24	13 / 21	20 - 615	NORMAL OVER LOGNORMAL	187.03
AROCLOR-1260	-	3 / 21	160 - 1500	NORMAL OVER LOGNORMAL	273.32
DELTA-BHC	-	2 / 21	2.2 - 3.2	NORMAL OVER LOGNORMAL	3.20
DIELDRIN	-	1 / 21	4.8	NORMAL OVER LOGNORMAL	4.8
ENDOSULFAN II	-	5 / 21	3.8 - 11	NORMAL OVER LOGNORMAL	11
ENDOSULFAN SULFATE	-	1 / 21	8.8	NORMAL OVER LOGNORMAL	8.8
ENDRIN	5.5	13 / 21	6 - 48	NORMAL	22.35
ENDRIN ALDEHYDE	-	3 / 18	12 - 44	NORMAL OVER LOGNORMAL	13.56
ENDRIN KETONE	-	2 / 21	7.9 - 10	NORMAL OVER LOGNORMAL	10
GAMMA-CHLORDANE	-	8 / 19	0.98 - 7.1	NORMAL OVER LOGNORMAL	3.92
2-METHYLNAPTHALENE	-	1 / 7	320	NONPARAMETRIC DIST	320
4-METHYLPHENOL	200	2 / 19	420 - 1400	NORMAL	1400
ACENAPHTHENE	-	12 / 19	44 - 3500	NORMAL	1881
ACENAPHTHYLENE	-	4 / 19	100 - 270	NORMAL	270
ANTHRACENE	97	19 / 19	82 - 8300	NORMAL	2787
BENZO(A)ANTHRACENE	380	19 / 19	390 - 20000	NORMAL	9960
BENZO(A)PYRENE	560	19 / 19	360 - 17000	NORMAL	8096
BENZO(B)FLUORANTHENE	830	19 / 19	540 - 25000	NORMAL	11466
BENZO(G,H,I)PERYLENE	370	19 / 19	290 - 13000	NORMAL	5230
BENZO(K)FLUORANTHENE	290	19 / 19	210 - 20000	NORMAL	5400
BIS(2-ETHYLHEXYL)PHTHALAT	-	15 / 15	210 - 7900	NORMAL	3539
BUTYLBENZYL PHTHALATE	-	4 / 18	41 - 380	NORMAL	380
CARBAZOLE	240	17 / 17	61 - 5700	NORMAL	2348
CHRYSENE	590	19 / 19	390 - 24000	NORMAL	11094
DI-N-BUTYL PHTHALATE	59	2 / 12	50 - 310	NORMAL	310
DI-N-OCTYLPHTHALATE	-	2 / 7	765 - 860	NONPARAMETRIC DIST	860
DIBENZO(A,H)ANTHRACENE	53	10 / 19	130 - 5300	NORMAL	1782
DIBENZOFURAN	-	9 / 19	52 - 2400	NORMAL	1669
FLUORANTHENE	1400	19 / 19	940 - 43000	NORMAL	19725
FLUORENE	47	15 / 19	63 - 5900	NORMAL	2000
INDENO(1,2,3-CD)PYRENE	320	19 / 19	240 - 14000	NORMAL	5765
NAPHTHALENE	-	2 / 19	60 - 530	NORMAL	530
PYRENE	760	19 / 19	680 - 40000	NORMAL	18429
1,1,1-TRICHLOROETHANE	-	1 / 25	2	NORMAL OVER LOGNORMAL	2
1,1-DICHLOROETHENE	-	1 / 25	3	NORMAL OVER LOGNORMAL	3
1,2-DICHLOROETHENE (TOTAL	-	6 / 25	2 - 22	NORMAL OVER LOGNORMAL	18.33
2-BUTANONE	9	3 / 23	3 - 45	NORMAL OVER LOGNORMAL	13.83
ACETONE	-	1 / 11	108	NORMAL OVER LOGNORMAL	35.26
CARBON TETRACHLORIDE	-	1 / 25	28	NORMAL OVER LOGNORMAL	18.64
CHLOROFORM	-	2 / 25	4 - 14.75	NORMAL OVER LOGNORMAL	14.75
CHLOROMETHANE	-	1 / 25	21	NORMAL OVER LOGNORMAL	18.67
ETHYLBENZENE	-	1 / 25	4	NORMAL OVER LOGNORMAL	4
TETRACHLOROETHENE	-	9 / 24	2 - 130	NORMAL OVER LOGNORMAL	32.73
TOLUENE	4	1 / 24	82	NORMAL OVER LOGNORMAL	22.80
TRICHLOROETHENE	-	12 / 25	2 - 1300	NORMAL OVER LOGNORMAL	160.41
XYLENE (TOTAL)	-	1 / 13	19	NORMAL OVER LOGNORMAL	14.16

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X
** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TAF

TAL 23

OCCURRENCE AND DISTRIBUTION OF INORGANICS IN SEDIMENT AT AREA A

NAWC WARMINSTER, PENNSYLVANIA

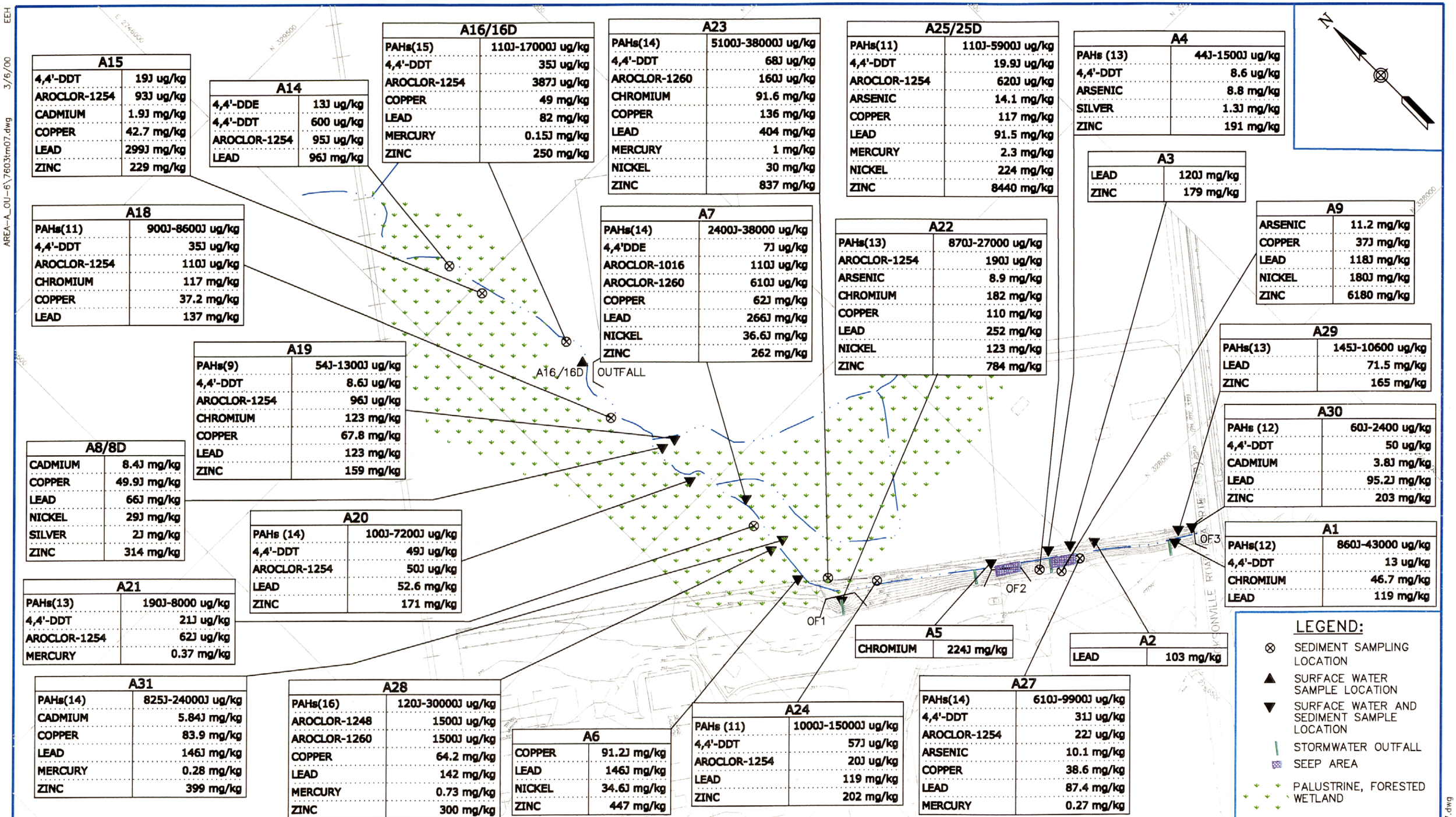
(mg/kg)

	BACKGROUND	SITE-RELATED			
SUBSTANCE	REPRESENTATIVE CONCENTRATION*	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION**	STATISTICAL DISTRIBUTION	REPRESENTATIVE CONCENTRATION
ALUMINUM	5420	27 / 27	4500 - 15650	NORMAL	8897
ARSENIC	2.8	25 / 25	2 - 14.05	NORMAL	6.71
BARIUM	65.9	25 / 26	62.7 - 1060	NORMAL OVER LOGNORMAL	247.88
BERYLLIUM	0.62	25 / 25	0.5 - 2.1	NORMAL	1.25
CADMIUM	-	7 / 9	0.2 - 8.4	NONPARAMETRIC DIST	8.4
CALCIUM	1290	25 / 25	1060 - 30200	NORMAL	11374
CHROMIUM	11.7	27 / 27	13.7 - 224	NORMAL OVER LOGNORMAL	74.46
COBALT	4.4	23 / 23	3.4 - 75.2	NORMAL OVER LOGNORMAL	21.96
COPPER	8.2	26 / 26	13.5 - 136	NORMAL	62.35
IRON	11200	27 / 27	10800 - 115500	NORMAL	34966
LEAD	24.6	27 / 27	23.9 - 404	NORMAL	151.77
MAGNESIUM	1320	26 / 26	1390 - 15000	NONPARAMETRIC DIST	7728
MANGANESE	289	27 / 27	115 - 11400	NORMAL	2389
MERCURY	-	16 / 27	0.09 - 2.25	NORMAL OVER LOGNORMAL	0.4
NICKEL	6.3	27 / 27	6.3 - 224	NORMAL OVER LOGNORMAL	52.62
POTASSIUM	492	25 / 25	451 - 3080	NONPARAMETRIC DIST	1762
SELENIUM	-	4 / 27	0.15 - 1.9	NORMAL OVER LOGNORMAL	0.48
SILVER	-	3 / 24	0.8 - 2	NORMAL OVER LOGNORMAL	0.94
SODIUM	340	16 / 16	176 - 2340	NORMAL	853.41
VANADIUM	13.6	27 / 27	14.5 - 157	NORMAL OVER LOGNORMAL	51.81
ZINC	3889	26 / 26	61 - 8435	NORMAL OVER LOGNORMAL	1101

* = REPRESENTATIVE CONCENTRATION FOR BACKGROUND IS PRESENTED IN TABLE X-X

** = QUALIFIERS FOR DATA ARE PRESENTED IN DATA PRESENTATION TABLES

EEH 3/6/00 AREA-A_OU-6\7603tm07.dwg



A15	
4,4'-DDT	19J ug/kg
AROCLOR-1254	93J ug/kg
CADMIUM	1.9J mg/kg
COPPER	42.7 mg/kg
LEAD	299J mg/kg
ZINC	229 mg/kg

A14	
4,4'-DDE	13J ug/kg
4,4'-DDT	600 ug/kg
AROCLOR-1254	95J ug/kg
LEAD	96J mg/kg

A16/16D	
PAHs(15)	110J-17000J ug/kg
4,4'-DDT	35J ug/kg
AROCLOR-1254	387J ug/kg
COPPER	49 mg/kg
LEAD	82 mg/kg
MERCURY	0.15J mg/kg
ZINC	250 mg/kg

A23	
PAHs(14)	5100J-38000J ug/kg
4,4'-DDT	68J ug/kg
AROCLOR-1260	160J ug/kg
CHROMIUM	91.6 mg/kg
COPPER	136 mg/kg
LEAD	404 mg/kg
MERCURY	1 mg/kg
NICKEL	30 mg/kg
ZINC	837 mg/kg

A25/25D	
PAHs(11)	110J-5900J ug/kg
4,4'-DDT	19.9J ug/kg
AROCLOR-1254	620J ug/kg
ARSENIC	14.1 mg/kg
COPPER	117 mg/kg
LEAD	91.5 mg/kg
MERCURY	2.3 mg/kg
NICKEL	224 mg/kg
ZINC	8440 mg/kg

A4	
PAHs (13)	44J-1500J ug/kg
4,4'-DDT	8.6 ug/kg
ARSENIC	8.8 mg/kg
SILVER	1.3J mg/kg
ZINC	191 mg/kg

A3	
LEAD	120J mg/kg
ZINC	179 mg/kg

A18	
PAHs(11)	900J-8600J ug/kg
4,4'-DDT	35J ug/kg
AROCLOR-1254	110J ug/kg
CHROMIUM	117 mg/kg
COPPER	37.2 mg/kg
LEAD	137 mg/kg

A7	
PAHs(14)	2400J-38000 ug/kg
4,4'DDE	7J ug/kg
AROCLOR-1016	110J ug/kg
AROCLOR-1260	610J ug/kg
COPPER	62J mg/kg
LEAD	266J mg/kg
NICKEL	36.6J mg/kg
ZINC	262 mg/kg

A22	
PAHs(13)	870J-27000 ug/kg
AROCLOR-1254	190J ug/kg
ARSENIC	8.9 mg/kg
CHROMIUM	182 mg/kg
COPPER	110 mg/kg
LEAD	252 mg/kg
NICKEL	123 mg/kg
ZINC	784 mg/kg

A9	
ARSENIC	11.2 mg/kg
COPPER	37J mg/kg
LEAD	118J mg/kg
NICKEL	180J mg/kg
ZINC	6180 mg/kg

A29	
PAHs(13)	145J-10600 ug/kg
LEAD	71.5 mg/kg
ZINC	165 mg/kg

A19	
PAHs(9)	54J-1300J ug/kg
4,4'-DDT	8.6J ug/kg
AROCLOR-1254	96J ug/kg
CHROMIUM	123 mg/kg
COPPER	67.8 mg/kg
LEAD	123 mg/kg
ZINC	159 mg/kg

A30	
PAHs (12)	60J-2400 ug/kg
4,4'-DDT	50 ug/kg
CADMIUM	3.8J mg/kg
LEAD	95.2J mg/kg
ZINC	203 mg/kg

A8/8D	
CADMIUM	8.4J mg/kg
COPPER	49.9J mg/kg
LEAD	66J mg/kg
NICKEL	29J mg/kg
SILVER	2J mg/kg
ZINC	314 mg/kg

A20	
PAHs (14)	100J-7200J ug/kg
4,4'-DDT	49J ug/kg
AROCLOR-1254	50J ug/kg
LEAD	52.6 mg/kg
ZINC	171 mg/kg

A1	
PAHs(12)	860J-43000 ug/kg
4,4'-DDT	13 ug/kg
CHROMIUM	46.7 mg/kg
LEAD	119 mg/kg

A21	
PAHs(13)	190J-8000 ug/kg
4,4'-DDT	21J ug/kg
AROCLOR-1254	62J ug/kg
MERCURY	0.37 mg/kg

A5	
CHROMIUM	224J mg/kg

A2	
LEAD	103 mg/kg

A31	
PAHs(14)	825J-24000J ug/kg
CADMIUM	5.84J mg/kg
COPPER	83.9 mg/kg
LEAD	146J mg/kg
MERCURY	0.28 mg/kg
ZINC	399 mg/kg

A28	
PAHs(16)	120J-30000J ug/kg
AROCLOR-1248	1500J ug/kg
AROCLOR-1260	1500J ug/kg
COPPER	64.2 mg/kg
LEAD	142 mg/kg
MERCURY	0.73 mg/kg
ZINC	300 mg/kg

A6	
COPPER	91.2J mg/kg
LEAD	146J mg/kg
NICKEL	34.6J mg/kg
ZINC	447 mg/kg

A24	
PAHs (11)	1000J-15000J ug/kg
4,4'-DDT	57J ug/kg
AROCLOR-1254	20J ug/kg
LEAD	119 mg/kg
ZINC	202 mg/kg

A27	
PAHs(14)	610J-9900J ug/kg
4,4'-DDT	31J ug/kg
AROCLOR-1254	22J ug/kg
ARSENIC	10.1 mg/kg
COPPER	38.6 mg/kg
LEAD	87.4 mg/kg
MERCURY	0.27 mg/kg

0 150 300
SCALE IN FEET

DRAWN BY LDL\EEH	DATE 2/29/00
CHECKED BY	DATE
REVISED BY	DATE
SCALE AS NOTED	

Tetra Tech NUS, Inc.

SEDIMENT CONCENTRATIONS
SCREENING CRITERIA EXCEEDANCES
AREA A
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY Tea	DATE 4/23/00
DRAWING NO. FIGURE 4-26	REV.

AREA-A_OU-6\7603tm07.dwg

442B30Y

which are downstream of Area A; from samples A5-SD and A9-SD, which are located generally downstream of Sites 2 and 3; and from samples A22-SD, A23-SD, and A25/25D-SD, which were generally downstream of Sites 2 and 3.

4.9 CONCLUSIONS

Significant conclusions regarding the nature and extent of contaminants in media other than groundwater at Area A are as follows:

- Post-removal surface soils within Area A exhibited the presence of only two compounds, benzo(a) pyrene and lead, above the screening criteria. The lead level was below the clean-up goal of 1,000 mg/kg established for the removal of surface soils in Site 2.

- No soil-to-groundwater SSLs were exceeded for the post-removal Site 1 surface soils; thallium was contained in one post-removal Site 3 surface soil sample at a level slightly above the SSL. Chromium was detected in several Site 2 surface soil samples at levels above the SSL. No clear pattern of the chromium exceedances was observed. Dieldrin was the only organic compound detected above its SSL in Area A post-removal surface soils.

- Post-removal subsurface soils within Area A contained several PAHs, arsenic, and lead at concentrations greater than the screening criteria.

- Several inorganic compounds exceeded their respective SSLs in Area A subsurface soils, including antimony, cadmium, chromium, lead, thallium, and silver. Antimony has not been detected in on-base Area A groundwater samples to date.

- Organic compounds detected in post-removal subsurface soil samples that exceeded the SSLs included pentachlorophenol, 3,3-dichlorobenzidine, dieldrin, methylene chloride, carbazole, benzo(a)anthracene, benzo(a) pyrene, dibenz(a,h)anthracene, and hexachloroethane. To date, pentachlorophenol, 3,3-dichlorobenzidine, and the PAH compounds have not been detected in Area A groundwater.

- Low levels of VOCs were detected in Area A surface water, including TCE (maximum of 2J ug/l), PCE (maximum of 1J ug/l), carbon disulfide (6J ug/l), and cloromethane (4J ug/l). Semivolatile organics, pesticides, and PCBs were generally not found, and, if detected, these concentrations did not exceed 1 ug/l in the Area A surface water samples.

- Sample A22-SW, taken from within Outfall No. 1, contained total metal concentrations of barium (147 ug/l), lead (16.9 ug/l), manganese (320 ug/l), and zinc (31.3 J ug/l) that were greater than background and were the maximum or near the maximum observed for Area A related surface water samples. This suggests that total metal concentrations observed in the OFI outfall sample are a contributing factor to elevated inorganic concentrations in surface waters adjacent to Area A.

- Several VOCs were found above background concentrations in Area A sediment samples. Sediment samples collected closest to OFI had the most frequent VOC detections. The maximum TCE (1,300 ug/l) and PCE (98 ug/lkg) concentrations were detected in sample A20-SD collected approximately 250 feet downstream from OFI.

- Several pesticides, PCBs, and semivolatile organics were detected in Area A sediment samples. The compounds most frequently detected above background in the sediment samples included PCBs and PAHs. The highest PAH concentrations were found in the sediment sample from OFI. At this location, PAH levels ranged from 1,300J to 27,000J ug/kg.

5.0 CONTAMINANT FATE AND TRANSPORT

Several aspects of contaminant fate and transport at Area A are discussed in this section. Various chemical and physical properties affecting contaminant migration are discussed in Section 5.1. Potential contaminant migration routes are identified and discussed in Section 5.2. Section 5.3 presents a brief discussion of contaminant persistence.

5.1 PHYSICAL AND CHEMICAL TRANSPORT PROPERTIES

This section provides a qualitative discussion of potential migration of the contaminants found at Area A. The physical and chemical properties of the chemicals found in the study area, where available, are presented in Table 5-1. These properties or parameters may be used to assess the behavior of a chemical in the environment.

Empirically determined literature values of water solubility, octanol-water partition coefficient (Kow), organic carbon/chemical partitioning coefficient (Koc), vapor pressure, Henry's Law constant, bioconcentration factor (BCF), and specific gravity are presented for organic chemicals, as available. Many of these parameters are not applicable to inorganic chemicals. For inorganics, specific gravity and BCFs have been presented, along with qualitative descriptions of important environmental fate properties. Calculated values, which were obtained using approximation methods, are presented when literature values are unavailable. A discussion of the environmental significance of each of these parameters follows.

The rate at which a chemical is leached from a waste deposit by infiltrating precipitation is a function of its water solubility. More soluble chemicals are expected to enter water much more readily and rapidly than less soluble chemicals. The water solubilities presented in Table 5-1 indicate that the VOCs are several orders of magnitude more water soluble than SVOCs (including phthalates and PAHs), pesticides, or PCBs. This conclusion is reinforced by the fact that VOCs are typically discovered more frequently and at greater concentrations in groundwater than less soluble chemicals. (Volatilization of VOCs from surface media is also an important factor in the observed distribution of these chemicals.)

Although phthalates, PAHs, and PCBs were detected in soil, such compounds have not been detected to a great extent in groundwater. When detected, they are observed in monitoring wells, where they may be part of the sediment in the sample instead of the aqueous fraction. This is a manifestation of their limited water solubility and tendency to adsorb onto soil/sediment particles.

The Kow is a measure of the equilibrium partitioning of a chemical between octanol and water. The Kow is also used to estimate BCFs in aquatic organisms. A linear relationship between the Kow and the uptake of chemicals by fatty tissues of animal and human receptors has been determined (Lyman et al., 1990).

SUMMARY OF PHYSICAL AND CHEMICAL DATA FOR HAZARDOUS SUBSTANCES
AREA A MEDIA OTHER THAN GROUNDWATER
NAWC WARMINSTER, PENNSYLVANIA

CHEMICAL OF CONCERN	MOLECULAR WEIGHT	SOLUBILITY (mg/L)	Log Kow	VAPOR PRESSURE (mmHg, 20C)	HENRY'S LAW CONSTANT (atm cu. m/mol)	BIOCONCENTRATION FACTOR (ug/kg/ug/L)	SPECIFIC GRAVITY	Koc
VOLATILES								
1,1,1-TRICHLOROETHANE	133.41	720	2.47	1.23E2 (25C)	3.00E-02	8.10E+01	1.35	1.52E+01
1,1,2,2-TETRACHLOROETHANE	167.86	3.10E+03	-	6.80E-03	3.70E-04	-	-	7.94E+01
1,1-DICHLORETHANE	98.96	5500	1.79	1.80E+02	4.26E-03	1.90E+01	1.174	3.00E+01
1,1-DICHLOROETHENE	96.94	400	1.48	5.91E+02	1.90E-01	5.30E+01	1.218	6.50E+01
1,2-DICHLOROETHENE (TOTAL)	96.94	800 (20C)	-	200 (25C)	4.08E-03	4.80E+01	1.28	5.90E+01
TRANS-1,3-DICHLOROPROPENE	110.97	2.80E+03	-	3.80E-02	1.50E-03	-	-	-
ACETONE	58.08	6.80E+05	-0.24	2.70E+02	3.43E-05	3.00E-01	0.791	9.20E+00
2-BUTANONE	72.1	35300	0.26	7.80E+01	2.08E-05	6.00E-01	0.805	1.70E+01
BENZENE	78.12	1780	2.13	95.2 (25C)	5.50E-03	7.84E+00	-	6.50E+01
BROMOMETHANE	94.95	1.40E+04	-	2.2	1.40E-02	-	-	1.70E+02
CARBON DISULFIDE	76.14	2300	1.84	2.60E+02	1.13E-02	1.10E+01	1.263	1.42E+02
CARBON TETRACHLORIDE	153.82	785	2.64	9.00E+01	2.30E-02	2.11E+02	1.59	4.39E+02
CHLOROBENZENE	113	4.10E+02	-	1.60E-02	4.47E-03	-	-	2.04E+02
CHLOROETHANE	64.52	5740	1.54	1.00E+03	4.00E-02	-	0.879	4.17E+01
CHLOROMETHANE	50.94	6450	0.95	3.76E+03	4.00E-02	3.20E+00	0.991	4.30E+00
CHLOROFORM	119.38	8200	1.97 (20C)	1.50E+02	2.88E-03	5.56E+00	1.489	4.40E+01
ETHYLBENZENE	106.16	152	3.15	7.00E+00	6.60E-03	6.68E+01	0.867	1.10E+03
METHYLENE CHLORIDE	84.93	1.70E+04	-	4.90E-01	2.40E-03	-	-	1.58E+01
TETRACHLOROETHENE	165.83	200	2.6 (20C)	1.40E+01	1.53E-02	2.52E+02	1.626	3.64E+02
TOLUENE	92.13	534.8 (25C)	2.69 (20C)	2.87E+01	6.66E-03	2.50E+01	0.867	3.00E+02
TRICHLOROETHENE	131.39	1100	2.53	5.79E+01	9.10E-03	9.70E+01	1.46	1.26E+02
XYLENE (TOTAL)	106.16	187	2.77-3.2	6.50E+00	4.33E-63	1.50E-02	0.86-0.88	2.48E+02
SEMIVOLATILES								
1,4-DICHLOROBENZENE	147.01	73	-	1.40E-03	2.80E-03	-	-	5.13E+02
2-METHYLNAPHTHALENE	142.19	26-28 (25C)	4.26	0.087 (25C)	6.00E-04	1.00E+03	0.994	5.80E+03
2-NITROPHENOL	139.11	2.10E+03	-	1.30E-03	8.70E-05	-	-	3.72E+01
3,3'-DICHLOROBENZIDINE	253.13	3.5	-	2.90E-10	2.10E-08	-	-	2.24E+04
4-METHYL-2-PENTANONE	100.2	2.00E+04	-	2.50E-02	1.20E-04	-	-	1.74E+01
4-METHYLPHENOL	108.1	4400	1.92/1.94	4.00E-02	1.29E-06	1.10E+01	1.0347	2.43E+01
4-NITROPHENOL	139.11	1.60E+04	-	2.90E-03	2.50E-05	-	-	2.34E+02
ACENAPHTHENE	154.2	3.42 (25C)	3.92	1.55E-3 (25C)	9.10E-05	1.80E+03	1.0242	4.60E+03
ACENAPHTHYLENE	152.2	3.93 (25C)	3.72	2.90E-02	1.45E-03	1.00E+03	-	2.50E+03
ANTHRACENE	178.2	0.045 (25C)	4.45	1.7E-5 (25C)	8.60E-05	4.70E+03	1.283	1.40E+04
BENZO(A)ANTHRACENE	228.28	0.0057	5.61	2.20E-08	1.00E-06	5.30E+04	-	2.00E+05
BENZO(A)PYRENE	252	0.0038 (25C)	5.98	5.60E-09	4.90E-07	1.09E+04	-	5.50E+06
BENZO(B)FLUORANTHENE	252.3	0.0014 (25C)	6.57	5.00E-07	1.22E-05	1.40E+05	-	5.50E+05
BENZO(G,H,I)PERYLENE	276	0.00026 (25C)	7.23	1.03E-10 (25C)	1.44E-07	3.50E+05	-	1.60E+06
BENZO(K)FLUORANTHENE	252.3	0.0043 (25C)	6.84	5.00E-07	3.87E-05	1.40E+05	-	5.50E+05
BIS(2-ETHYLHEXYL)PHTHALATE	390.62	0.4 (25C)	5.3	2.00E-07	3.00E-07	2.30E+08	0.99	2.00E+09
BUTYLBENZYLPHTHALATE	312	2.9	4.78	6.00E-05	8.30E-06	4.70E+04	1.1 (25C)	1.70E+05
CARBAZOLE	167.21	-	3.29	400 (323C)	-	-	1.1	1.20E+03
CHRYSENE	228.3	0.0018 (25C)	5.61	6.3E-9 (25C)	1.05E-06	5.30E+04	1.274	2.00E+05
DI-N-BUTYLPHTHALATE	278.35	4.00E+02	5.20E+00	1.00E-01	2.80E-07	8.90E+01	1	5.23E+00
DI-N-OCTYLPHTHALATE	391	3 (25C)	9.2	1.40E-04	1.70E-05	3.90E+08	0.99	3.60E+09
DIBENZ(A,H)ANTHRACENE	278.4	0.005 (25C)	5.97	1.00E-10	7.30E-08	6.90E+05	-	3.30E+06

- = Physical or chemical properties not available for this chemical in this classification

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AREA A MEDIA OTHER THAN GROUNDWATER
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CHEMICAL OF CONCERN	MOLECULAR WEIGHT	SOLUBILITY (mg/L)	Log Kow	VAPOR PRESSURE (mmHg, 20C)	HENRY'S LAW CONSTANT (atm cu. m/mol)	BIOCONCENTRATION FACTOR (ug/kg/ug/L)	SPECIFIC GRAVITY	Koc
SEMIVOLATILES (CONTINUED)								
DIBENZOFURAN	168.2	10	4.12	-	-	-	-	8.13E+03
DIETHYLPHTHALATE	222.2	210	2.47	3.5E-3 (25C)	1.20E-06	1.07E+02	1.12	1.42E+02
FLUORANTHENE	202.3	0.26 (25C)	5.33	5E-6 (25C)	6.50E-06	1.20E+04	1.252	3.80E+04
FLUORENE	116.2	1.69 (25C)	4.18	7.10E-04	6.40E-05	3.80E+03	1.203	7.30E+03
HEXACHLOROETHANE	236.76	4.10E+01	-	6.20E-04	3.60E-03	-	-	2.19E+03
INDENO(1,2,3-CD)PYRENE	276.3	0.00053 (25C)	7.66	1.00E-10	6.95E-08	3.50E+05	-	1.60E+06
N-NITROSODIPHENYLAMINE (1)	198.23	3.50E+01	2.79E+00	1.00E-01	3.10E+00	1.40E+02	-	2.81E+00
NAPHTHALENE	128.2	31.7 (25C)	3.01/3.45	8.7E-3 (25C)	4.60E-04	4.20E+02	1.152	9.40E+02
PENTACHLOROPHENOL	266	1.30E+01	-	7.10E-07	1.40E-05	-	-	2.00E+04
PYRENE	202.3	0.13 (25C)	5.18	2.5E-6(25C)	5.10E-06	1.20E+04	-	3.80E+04
PESTICIDES/PCBs								
4,4'-DDD	320.1	0.09 (25C)	1.60E+06	1.2E-7 (25C)	2.20E-08	1.80E+05	-	7.70E+05
4,4'-DDE	318	0.04 (20C)	4.28	6.50E-06	6.80E-05	8.00E+06	-	4.40E+06
4,4'-DDT	354.5	0.0055 (25C)	6.19 (20C)	1.9E-7 (25C)	1.58E-05	8.00E+06	-	3.90E+06
ALDRIN	364.91	1.70E-02	5.11E+00	2.30E-06	5.00E-04	4.70E+03	1.7	4.98E+00
ALPHA-CHLORDANE	409.8	5.60E-02	2.78E+00	1.00E-05	3.70E-05	1.40E+03	1.11	5.15E+00
AROCLOR-1242	254	8.00E-02	-	1.00E-07	4.10E-04	-	-	4.79E+04
AROCLOR-1248	299.5	0.054	5.75	4.9E-4 (25C)	3.60E-03	-	-	2.50E+05
AROCLOR-1254	325.1	3.10E-02	6.04E+00	7.70E-05	2.60E-03	3.10E+04	-	5.72E+00
AROCLOR-1260	375.7	0.08 (24C)	7.15	4E-5 (25C)	0.74	1.00E+05	-	6.70E+06
BETA-BHC	290.85	0.54	-	6.50E-10	3.50E-07	-	-	2.29E+03
DELTA-BHC	290.85	2.10E+01	4.14E+00	2.00E-02	2.50E-07	1.30E+02	1.9	3.58E+00
DIELDRIN	380.91	1.90E-01	4.09E+00	1.80E-07	5.80E-05	4.70E+03	1.8	3.23E+00
ENDOSULFAN I	406.95	3.20E-01	-	1.30E-08	1.70E-05	-	-	2.04E+03
ENDOSULFAN II	406.95	3.30E-01	3.62E+00	1.00E-05	1.91E-05	2.70E+02	1.7 (20/20C)	2.30E+00
ENDOSULFAN SULFATE	422.92	2.20E-01	3.66E+00	NA	2.60E-05	-	-	1.62E+00
ENDRIN	380.92	2.60E-01	5.60E+00	2.00E-07	4.00E-07	4.00E+03	1.7	3.23E+00
ENDRIN ALDEHYDE	380.92	2.60E-01	5.60E+00	2.00E-07	3.90E-07	4.00E+03	-	2.83E+00
ENDRIN KETONE	380.92	-	-	-	4.00E-07	7.10E-02	-	-
GAMMA-CHLORDANE	409.8	5.60E-02	2.78E+00	1.00E-05	3.70E-05	1.40E+03	1.11	5.15E+00
GAMMA-BHC	290.85	4.20E+00	-	4.90E-08	3.40E-06	-	-	1.38E+03
HEPTACHLOR	373.35	2.70E-01	-	4.30E-07	5.80E-04	-	-	6.76E+03
HEPTACHLOR EPOXIDE	389.2	2.70E-01	-	5.70E-09	8.30E-06	-	-	2.09E+04
METHOXYCHLOR	345.65	4.00E-02	4.68E+00	-	3.00E-05	8.30E+03	1.4	4.90E+00
DIOXINS/FURANS								
2,3,7,8-TCDD**	322	0.000019	-	9.70E-13	9.20E-06	-	-	4.27E+06

- = Physical or chemical properties not available for this chemical in this classification

** 2,3,7,8-TCDD was not detected at NAWC Warminster, but the physical/chemical properties listed here are presented as an indication of the properties of other dioxin/furan congeners

SUMMARY OF PHYSICAL AND CHEMICAL DATA FOR HAZARDOUS SUBSTANCES
AREA A MEDIA OTHER THAN GROUNDWATER
NAWC WARMINSTER, PENNSYLVANIA

CHEMICAL OF CONCERN	MOLECULAR WEIGHT	SOLUBILITY (mg/L)	Log Kow	VAPOR PRESSURE (mmHg, 20C)	HENRY'S LAW CONSTANT (atm cu. m/mol)	BIOCONCENTRATION FACTOR (ug/kg/ug/L)	SPECIFIC GRAVITY	Koc
INORGANICS								
ALUMINUM	26.98	INSOLUBLE	-	0	-	-	2.708	-
ANTIMONY	121.75	-	-	1 (886C)	-	1.00E+00	6.684	-
ARSENIC	74.92	-	-	1 (372C)	-	4.40E+01	5.72	-
BARIUM	137.34	DECOMPOSE	-		-	1.00E+00	3.5	-
BERYLLIUM	9.01	-	-	1 (1520C)	-	1.90E+01	1.85	-
CADMIUM	112.4	INSOLUBLE	-	1 (1284C)	-	6.40E+01	8.642	-
CALCIUM	40.08	DECOMPOSE	-		-	-	1.57	-
CHROMIUM	52	INSOLUBLE	-	0	-	1.60E+01	7.2	-
COBALT	58.93	INSOLUBLE	-	0	-	1.00E+00	8.9	-
COPPER	63.54	INSOLUBLE	-	1 (1628C); 10 (1870C)	-	3.60E+01	8.92	-
IRON	55.85	INSOLUBLE	-	0	-	-	7.86	-
LEAD	207.19	INSOLUBLE	-	1 (980C)	-	1.00E+00	11.35	-
MAGNESIUM	24.312	-	-	-	-	-	1.738	-
MANGANESE	54.94	DECOMPOSE	-	1 (1292C)	-	1.00E+00	7.2	-
MERCURY	200.59	5.6E-03g/100cc	-	2E-03 (25C)	-	1.00E+00	13.5939	-
NICKEL	58.71	INSOLUBLE	-	1 (1810C)	-	4.70E+01	8.902	-
POTASSIUM	39.1	DECOMPOSE	-	-	-	-	0.862	-
SELENIUM	78.96	INSOLUBLE	-	0	-	1.00E+00	4.26-4.81	-
SILVER	107.87	INSOLUBLE	-	0	-	5.00E-01	10.5	-
SODIUM	22.9898	DECOMPOSE	-	-	-	-	0.97	-
THALLIUM	204.37	-	-	-	-	-	11.85	-
VANADIUM	50.94	-	-	-	-	1.00E+00	5.96	-
ZINC	65.37	-	-	1 (487C)	-	4.70E+01	7.133	-
CYANIDE	27	SOLUBLE	-	657.8 (21.9C)	-	-	0.699	-

- = Physical or chemical properties not available for this chemical in this classification

PAHs, phthalates, and PCBs are several orders of magnitude more likely to partition to fatty tissues than the more water-soluble VOCs. The Kow is also useful in characterizing the sorption of compounds by organic soils when experimental values are not available.

The Koc is related to the water solubility and the Kow. This parameter indicates the tendency of a chemical to bind to soil particles containing organic carbon. Chemicals with high Koc generally have low water solubilities and vice versa. Chemicals such as phthalates, PAHs, pesticides, and PCBs are relatively immobile in the subsurface environment and are preferentially bound to the soil phase. These compounds are not subject to groundwater transport to the same extent as compounds with high water solubilities.

Koc may be used to infer the relative rates at which the more mobile chemicals are transported in the groundwater. The Koc and the fractional organic carbon content of the soil (FOC) may be used to determine an equilibrium distribution coefficient (Kd) for the solid and aqueous matrices using the following relationship:

$$Kd = Koc \times FOC$$

where: Kd = Distribution coefficient
FOC = Soil organic carbon content
Koc = Organic carbon partition coefficient

TOC results may be used to calculate FOC for soils. One subsurface soil taken at Area A was analyzed for TOC, and the result was 2,600 mg/kg. Thus,

$$FOC = (2600 \text{ mg/kg})\ (1E\text{-}6 \text{ kg/mg})$$
$$= 0.0026 \text{ kg organic carbon/kg soil}$$

Vapor pressure provides an indication of the rate at which a chemical volatilizes from both soil and water. It is of primary significance in instances where environmental interfaces such as surface soil/air and surface water/air are important, rather than in evaluation of groundwater and subsurface soils. Vapor pressures for VOCs are generally many times higher than vapor pressures for phthalate esters and PAHs. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Volatilization has also been reported to be one of the environmental fate pathways of PCBs. For example, of 700,000 pounds of PCBs in uncapped landfills in the Hudson River Basin area, an estimated 3,000 pounds (about four percent) volatilize annually (Lunsford, 1982). Volatilization depends upon such factors as total exposed surface area, PCB concentrations, and amount of organic matter in the soil.

Both vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies. The Henry's Law Constant is the equilibrium vapor pressure of a chemical above a solution divided by its concentration in the solution (for dilute systems). The Henry's Law Constant may also be used to calculate the equilibrium contaminant concentrations in the vapor versus liquid phases for dilute solutions commonly encountered in environmental settings. The Henry's Law Constant is also useful for mass transfer applications for air-stripping column design.

BCFs represent the ratio of aquatic-organism tissue concentration to water concentration. The ratio is both contaminant and species specific, as well as tissue specific. When site-specific values are not measured, literature values may be used or the BCF may be derived from the Kow. Phthalate esters, PAHs, and pesticides will bioconcentrate at orders of magnitude greater than those concentrations found in the water where the exposed species reside. Bioconcentration is a well-known property of PCBs; PCBs can be stored in fatty tissues of exposed organisms at concentrations much higher than the environmental concentration. VOCs are not as readily bioconcentrated as pesticides or PCBs.

Specific gravity is the ratio of the mass of a given volume of pure chemical at a specified temperature to the mass of the same volume of water at a given temperature. Its primary use is to determine whether immiscible compounds or very high concentrations of a pure contaminant will float or sink in water. As shown in Table 5-1, most of the chemicals detected in this study area were denser than water, although ethylbenzene and xylenes are less dense.

According to EPA's Soil Screening Guidance (EPA, 1996a), most of the inorganic chemicals have a strong tendency to adsorb onto sediment particles, a factor that greatly reduces their mobility. For some metals, such as cadmium, lead, and mercury, bioaccumulation also plays an important role in environmental fate. While the metals themselves are insoluble in water, soluble species of some metals, such as chromium and antimony, can increase contaminant mobility.

5.2 POTENTIAL MIGRATION ROUTES

In general, numerous potential migration routes exist in areas contaminated with hazardous materials. Such migration routes include, but are not limited to, atmospheric migration via particulate or volatile/semivolatile emissions, overland migration of dissolved or adsorbed contaminants, surface water transport, and groundwater transport.

5.2.1 Atmospheric Migration via Vapor Emissions

The first possible route for contaminant migration from sites from within Area A through the air is the volatilization of compounds from surface water or subsurface soil (especially if exposed through excavation, erosion). The RI did not confirm that volatilization was occurring at or within Area A in a significant manner.

During the soil gas survey and the drilling of the confirmation borings, uniformly low to non-detected levels of volatile organic vapors were found, with the exception of one soil boring at Site 3. Furthermore, ambient air readings taken during all the invasive tasks conducted within Area A did not exceed normal background levels. The concentrations of VOCs detected in subsurface soil were relatively low, and volatile emissions from exposed subsurface soil would be expected to be negligible. VOCs were not detected in surface water downstream of Area A.

5.2.2 Atmospheric Migration via Particulate Emissions

Another possible scenario for contaminant migration is the generation of contaminant dusts from surface and subsurface soils during excavation or other construction activities (sediments are covered by water). This would be potentially important for metals and would depend upon the soil materials being exposed in some way. The 1998 soil removal actions at Site 1, Site 2, and Site 3 addressed the more contaminated soils at these sites. The presence of backfill material over the excavated locations and a vegetated soil cover in the vicinity of these sites has greatly reduced the potential for risks due to dust emissions. In the event soils are disturbed in the future, this migration route may have some relevance.

5.2.3 Subsurface Contaminant Migration to Surface Water and Sediment

Possible migration pathways for Area A soil contaminants to surface water are transport via groundwater or discharge of water perched above the water table. This process may be taking place because groundwater flow maps indicate that groundwater flow across Area A is to the north, toward the stream. Groundwater movement to the stream may be through both overburden and shallow bedrock. Some of the same compounds in monitoring wells, such as BTEX, PAHs, and phthalates, were detected in downstream surface water and sediment, although most of the chlorinated VOCs were not found. The conditions at Site 1 are not conducive to groundwater discharging to the stream, given groundwater flow directions, surface topography, and the greater distance to the stream.

On some occasions, minor seeps have been observed along the southern bank of this stream near Site 3 suggesting the potential for discharge of subsurface water perched above the water table. Seeps were observed along the creek embankment north of Site 3 during the Phase I and Phase III RI field work. During the Phase I RI, it was reported that a thin layer of orange-colored slime was observed at several points along the creek, suggesting that there may be more than one entrance point of the seep into the creek (SMC Martin, 1991). It was not known if the seep was spring fed. Seeps were not noticed during the Phase II RI.

During Phase III, at least three separate seeps or springs were observed along the creek embankment between the guard house and Jacksonville Road. The seeps did not appear to be flowing and had oxidized the surrounding soils and rock fragments. Separate visits to this portion of the creek have not always

revealed the presence of these seeps or springs. As they are positioned above the water table and flow intermittently, they appear to be transient seeps that are related to localized perched conditions within the overburden.

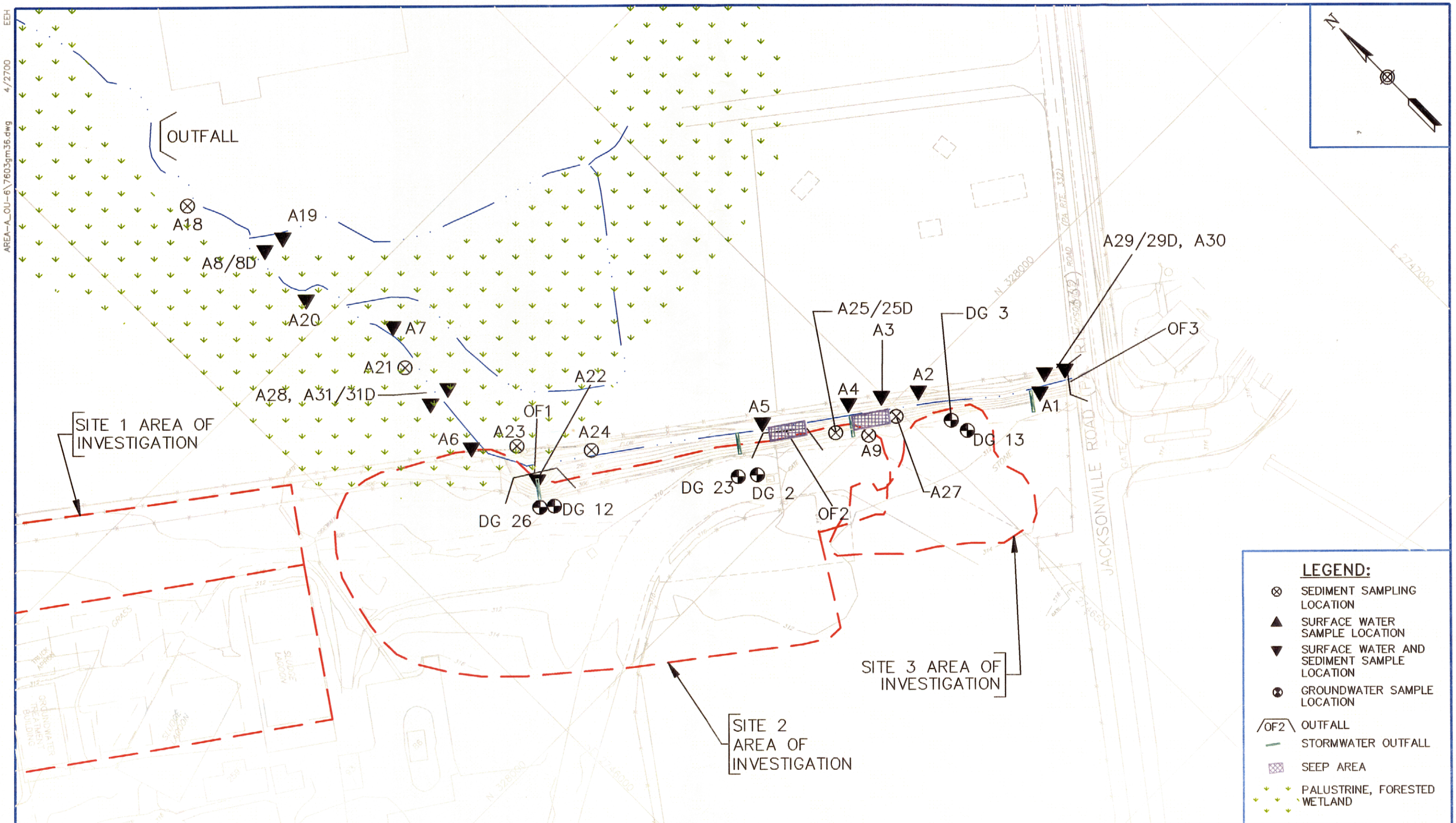
While shallow groundwater within Area A may discharge to the nearby stream, the stream's function as a groundwater discharge point is expected to be minor. The low overall permeability and minor saturated thickness of the overburden suggests that significant quantities of groundwater are not transported laterally through this flow system.

Groundwater seepage into the tributary might occur if the water table adjacent to the stream is higher than the stream's surface elevation. Based on April 1995 water level measurements (Focused RI for Groundwater, HNUS, 1995), a slight downward hydraulic head differential was observed between overburden and shallow bedrock (less than 50 feet deep) wells at cluster locations near the northern edge of Area A. Staff gauge measurements revealed the stream water elevation to be slightly below the groundwater elevations at Site 3 and well above the shallow groundwater elevations near Site 2. These data indicate little or no groundwater discharge to the stream near Sites 2 and 3.

Similarly a comparison of December 1997 water-level measurements (Summary Report for Areas A and D Groundwater Monitoring, B&R Environmental, 1998), elevations for overburden and shallow bedrock monitoring well pairs in the vicinity of Area A revealed a slight downward hydraulic head differential in these well pairs. The downward vertical hydraulic gradient indicates limited, if any, discharge of shallow groundwater to surface water.

Soils near Sites 2 and 3 are characterized as Urban land-Lansdale complex (Section 3.0). Most soils have been regraded, disturbed, filled over, or otherwise altered due to construction. The original soils near the stream consist primarily of silt loams. These soils tend to have slow to moderate permeabilities. In addition, the presence of roadways, parking lots, and other structures has reduced the available area for precipitation and surface runoff to recharge groundwater near these sites. Based on this information and visual observations, most of the flow in the unnamed tributary appears to be from the stream's headwaters area located across Jacksonville Road and upstream from Area A. However, during periods of high precipitation and storm events, seeps likely associated with perched water and subsurface flow above the water table have been observed.

To help evaluate this potential migration route, groundwater, surface water, sediment, and seep analytical results for samples collected near Sites 2 and 3 (Figure 5-1) were evaluated to determine if soil contaminants may be migrating to surface water via subsurface pathways. The following table reflects this comparison:



0 100 200
SCALE IN FEET

DRAWN BY LDL\EEH	DATE 4/27/00
CHECKED BY	DATE
REVISED BY	DATE
SCALE AS NOTED	

Tetra Tech NUS, Inc.

GROUNDWATER/STREAM SAMPLING LOCATIONS
AREA A
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603	
OWNER NO. 0601	
APPROVED BY Tea	DATE 4/27/00
DRAWING NO. FIGURE 5-1	REV.

442B31Y

AREA-A_OU-6\7603gm36.dwg 4/27/00 EEH

	CONTAMINANT CONCENTRATIONS		
CONTAMINANT	GROUNDWATER[1]	SURFACE WATER[2]	SEDIMENT/SEEP[3]
PCE	Non-detect - 7 ug/l	Non detect - 1J ug/l	Non-detect - 130 ug/kg
TCE	Non-detect - 1 ug/l	Non detect - 2J ug/l	Non-detect – 1300 ug/kg
Total 1,2-DCE	Non-detect - 2 ug/l	Non detect	Non-detect – 22 ug/kg
1,1,1-TCA	Non-detect - 10 ug/l	Non detect	Non-detect - 2J ug/kg.

For VOCs, it does not appear that groundwater contaminants have significantly affected surface water, sediment, or seep chemical concentrations. Sediment and seep samples have contained varying levels of semivolatile organic compounds, pesticides, and PCBs. Pesticides and PCBs have historically not been detected in overburden and shallow Area A groundwater, while semivolatile organics have only been detected at trace levels.

For inorganics, groundwater sample results (total inorganics) were compared to surface water samples tested for total inorganics and sediment samples taken along the stream between OF1 and Jacksonville Road. The results were as follows:

	CONTAMINANT CONCENTRATIONS		
CONTAMINANT	GROUNDWATER	SURFACE WATER	SEDIMENT/SEEP
Beryllium	Non-detect	Non-detect	0.5 mg/kg - 2.1 mg/kg
Cadmium	Non-detect	Non-detect - 2.5J ug/l	Non detect – 5.84J mg/kg
Copper	Non-detect - 1660 ug/l	Non-detect – 106 ug/l	22.6 ug/kg - 137 mg/kg
Lead	Non-detect - 233 ug/l	Non-detect – 28.5 ug/l	23.9 mg/kg – 404 mg/kg
Vanadium	Non-detect - 53 ug/l	Non-detect	14.8 mg/kg - 157 mg/kg
Zinc	Non-detect - 1,010 ug/l	20.8J ug/l – 117 ug/l	61 mg/kg – 8490 mg/kg

5.2.4 Surface Water and Sediment Transport

The primary migration route for stream contaminants in the surface water and sediment is via downstream flow. Contaminants may, to some degree, migrate from sediment to surface water and vice versa. However, metals and compounds with high organic carbon partition coefficient (Koc) such as PCBs and phthalates tend to bind strongly to sediment and migrate slowly, whereas lower-Koc, more highly soluble substances such as TCE and toluene would tend to stay in the surface water and migrate more rapidly (Versar, 1979). Bioconcentration by aquatic organisms may also be a significant environmental fate pathway for lead, mercury, DDT, PCBs (Versar, 1979; EPA, 1986a).

5.2.5 Soil Transport and Migration to Groundwater and Other Media

Rainwater that falls on the Area A sites may transport contaminants through runoff. Runoff can transport contaminants in surface soils in both the dissolved form and also in solid form sorbed to soil particles being eroded by the runoff. Contaminants that are transported with the surface water runoff migrate quickly (on the order of hours) so the contaminants do not have the opportunity to decay significantly before reaching

the receptor location. A surface water runoff fate and transport model can be used to estimate soil concentrations that are acceptable for protecting sediment quality. Appendix J provides such a model.

5.3 CONTAMINANT PERSISTENCE

Several transformation processes are believed to affect the persistence of organic chemicals in the environment. The primary processes affecting contaminant fate in the environment include microbial, photolytic, and chemical degradation.

In general, photolytic degradation is not considered to be a relevant degradation mechanism for monocyclic aromatic compounds such as toluene (EPA, 1982). Furthermore, even photodegradable compounds must be present in media exposed to sunlight for such degradation to occur (such as surface soil). Since VOCs were detected in subsurface soil and groundwater but not surface water, photolytic degradation is not expected. For PCBs, photolysis from surface media can occur, especially in the more highly chlorinated compounds, although the process is reported to be slow (Versar, 1979). Photolysis is considered to be insignificant for phthalates and of unknown significance for PAHs (Versar, 1979).

Generally, organic molecules are subject to several chemical reactions under environmental conditions. Such reaction mechanisms include acid/base reaction, addition, elimination, and hydrolysis. However, monocyclic aromatics are not particularly amenable to the majority of these degradation mechanisms. Hydrolysis is considered to be negligible for PAHs, halogenated hydrocarbon pesticides, and PCBs. Phthalates can be more susceptible (Versar, 1979; EPA, 1982; Lyman et al, 1990). Hydrolysis reactions can occur under acidic, basic, or neutral conditions.

Another possible type of degradation is the dechlorination of PCE and TCE to 1,2-DCE, 1,1-DCE, and ultimately vinyl chloride (Cline and Viste, 1984). A similar type of reaction has been reported for 1,1,1-TCA in degradation to 1,2-DCA, 1,1-DCA, and chloroethane.

Bacterial degradation is a potential environmental fate mechanism. The compounds for which biodegradation is potentially considerable are toluene, 4-methylphenol, and, to some extent, naphthalene and phthalates (EPA, 1982; Verschueren, 1983). This degradation is primarily biological, and anaerobic conditions are typically required for these reactions to occur.

6.0 BASELINE RISK ASSESSMENT

This section provides a description of the baseline risk assessment and risk ratio/toxicological evaluation (RR/TE) methods employed for Area A media other than groundwater, as well as a summary of the risk assessment results. The general objectives of the evaluation were to estimate the actual or potential risks to human health and the environment resulting from the presence of contamination in surface soil and subsurface soil following the removal action. Sections 6.1 through 6.6 discuss the human health portion of the risk assessment. For surface and subsurface soils, the evaluation was based on the nature and extent of contamination present at Area A after the soil removal actions were taken into consideration. Area A is divided into four areas: Site 1, Site 2, Site 3, and the Impoundment Area. Because these areas were initially investigated separately, the post-removal evaluation was also conducted separately and the results are presented and discussed for each of the four areas in this report.

A risk assessment was also performed to evaluate the actual or potential risks to human health and the environment due to the presence of contamination in surface water and sediment in the stream (an unnamed tributary of Little Neshaminy Creek) adjacent to the Area A sites. Section 6.7 addresses the ecological risk assessment associated with the stream.

6.1 HUMAN HEALTH RISK EVALUATION

The specific objectives of the RR/TE for surface and subsurface soils were as follows:

- To estimate the actual or potential risks to human health resulting from the presence of contamination in surface and subsurface soils after remedial actions.

- To provide a basis for attainment of concentrations that are protective of potential human receptors under industrial/commercial use, and hypothetical residential exposure scenarios.

In addition to these objectives, this section estimates the actual or potential risks to human health resulting from the presence of contamination in off-base surface water and sediment. These risks relate the stream adjacent to the Area A sites, which is an unnamed tributary of Little Neshaminy Creek.

Three major aspects of chemical contamination must be considered when assessing public health risks: (1) contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or by human action; (2) potential exposure points must exist either at the source or via migration pathways if exposure occurs at a remote location other than the source; and (3)

human or environmental receptors must be present at the point of exposure. Risk is a function of both toxicity and exposure; without any one of the three factors listed above, there is no risk.

In order to estimate the potential for human health risk attributable to post-remediation surface and subsurface soil, information regarding the toxicity of the compounds detected in the various media, the distribution of contamination, potential migration pathways, and a site-specific estimate of chemical intake via assumed exposure routes may be combined.

At sites where a removal action has taken place, a formal human health risk assessment may not always be necessary. Rather, a risk-ratio/toxicological evaluation method can be employed at these sites to determine whether further investigation, or a more conventional evaluation of risk, would be beneficial for the decision-making process. In essence, this procedure allows for a preliminary indication of potential risk to humans once chemicals of potential concern (COPCs) in soil have been identified before performing a more rigorous assessment, if deemed appropriate. The RR/TE method was not employed for the Area A stream, including affected surface water and sediment, since the quantitative evaluation of risk was deemed more appropriate.

Assessment of the potential health effects from lead was handled separately, as per EPA guidance. Appropriate lead models will be used, if warranted, for future hypothetical residential children should lead be selected as a COPC based on initial screening.

This post-remedial human health risk assessment for Area A was generally divided into data evaluation, risk ratio analysis, toxicological evaluation/risk characterization, lead modeling, and conclusions. Each section is briefly discussed below.

Data Evaluation (Section 6.2) is primarily concerned with data quality assessment, background comparison tests, identification of COPCs, distributional analysis of the data, and calculation of exposure point concentrations. The site-specific background and site data are analyzed and COPCs are selected that are representative of the environmental contaminants present at the site. Distributional analysis of the data is the basis for calculating an exposure point concentration (EPC), which provides the chemical input into each of the exposure pathways.

Risk Ratio Analysis (Section 6.3) describes the risk ratio process and contains tables of the results of this analysis for those chemicals identified as COPCs in the data evaluation and screening process.

Toxicological Evaluation and Risk Characterization (Section 6.4) presents the results of the evaluation for those COPCs that the risk ratio analysis determined warranted further evaluation.

Lead Modeling (Section 6.5) describes the model used and the results of the lead analysis.

Conclusions (Section 6.6) presents major conclusions of the human health risk assessment.

6.2 DATA EVALUATION

This section presents the approaches for data quality assessment, background comparison tests, identification of COPCs, distributional analysis of the data, and the calculation of exposure point concentrations. Four environmental media were sampled at Area A: on-site surface soil, on-site subsurface soil, off-base sediment, and off-base surface water.

6.2.1 Data Quality Assessment

Data quality was assessed using data usability worksheets that are consistent with Risk Assessment Guidance for Superfund (RAGs) - Part A (EPA, 1989a) and data quality assessment guidance (EPA, 1996a). These data usability worksheets act as a summary of important data quality issues and potential impacts of the issues on the quantitative HHRA. The data usability worksheets were divided into four main sections (Field Sampling, Analytical Techniques, Data Quality Objectives, and Data Validation and Interpretation). The results of the data usability worksheets for surface soil and subsurface soil show that no major data quality assessment issues were present for Area A; therefore, no impact on the quantitative HHRA was expected.

6.2.2 Background Comparison Tests

An array of statistical tests was performed to determine if results of samples from surface soil and subsurface soil were elevated relative to background sample results. The name of each test, the statistical question answered by the test, the assumptions required to run the test, and the criterion used by each test to judge whether site data are greater than background are delineated in the headings and footnotes to background comparison tables for surface and subsurface soils. These statistical procedures include quantitative tests that evaluate overall differences between the entire populations of site and background data values; hot spots; and the frequency of detection (proportion of detected versus non-detected values in site versus background) but not the magnitude of values.

Each statistical test was performed using a decision-making probability level (P-level) of 0.05, which means that, in situations where the test conclusion states that site-related results are greater than background, the chance of the test yielding a false conclusion caused by random variations in the data set is five percent or less. The overall conclusion (whether site results are greater than background) was assumed to be "yes" if any one of the quantitative tests concluded that site data are elevated above background. If no conclusion could be reached for any of the quantitative tests (e.g., if the assumptions necessary to run each of the

various tests were not valid), then the overall decision was based on the conclusions of the qualitative tests alone. Further information regarding each statistical test is presented below:

- The means of the two data sets were compared if the same type of distribution (normal or lognormal) was determined for both site and background data set. If the site and background data exhibited equal standard deviations (based upon Bartlett's test for equal variances), then the student's t-test was applied; otherwise, Satterthwaite's t-test was performed to determine if the site mean is greater than the background mean. The t-test is valid only if at least 85 percent of site data and 85 percent of background data are positive detects, there are at least three sampling points in each data set, and the pooled standard deviation is not zero.

- Nonparametric statistical tests, which do not require underlying assumptions regarding equal data distributions, were also applied in each case. The Mann-Whitney U-test was used to determine whether the site and background data are from populations with identical medians and rank distributions. The Mann-Whitney test involves combining the two data sets, ranking results from smallest to largest, and evaluating whether the two sites have a similar distribution of data within the range of low to high ranks. If more than 40 percent nondetected results are present in either the site or the background data set or when multiple levels of detection limits are present, a different statistically valid test, Gehan's test, was substituted because recent guidance (EPA, 1992b) indicates that the Mann- Whitney test is not valid in the aforementioned situations. (Gehan's test is statistically equivalent to the Mann-Whitney Test if all results are positive.) For either of these tests to work, not all data points can be tied and there must be at least two background data points. The Mann-Whitney U test and the Gehan's test statistics were computed using appropriate score adjustments for tied values and a normal approximation when sufficient data points were available; whereas, an exact computation of probabilities was used in the situations where there were very few (for example, less than eight) data points.

- A 95 percent upper tolerance limit (UTL) test was applied to determine whether the maximum concentration detected in an area of interest was a hot spot of a magnitude exceeding 95 percent of the background population. The 95 percent UTL is defined as the calculated upper limit that, on the average, is expected to include 95 percent of the background population. If the background data were determined to match the shape of a normal or lognormal population, then the limit was calculated using the t-distribution and the appropriate normal or log-transformed mean and standard deviation from the background data set. For this test to be valid, the background data set was required to be comprised of at least 85 percent detects and at least three data points.

- A substitute procedure for the 95 percent UTL, called the 95 percent quantile test, was employed to test for hot spots if the background data were not determined to be normally or log-normally

distributed. For the quantile test to be valid, at least 19 background data points were required, no detection limit could be greater than the UTL, and at least 10 percent of the data points must be detects in the background data set.

- The upper ranks test (EPA, 1992b, 1996a) is another hot spot test. This test combines the site and background data into one set and determines whether the major portion of a subset of the largest detected results is comprised chiefly of site data rather than an equal mixture of site and background. In this procedure, the probability is calculated that k or more samples from the largest r data points in the combined data set are comprised of site data, assuming that the site and background populations are equal. In the event that there is less than a five percent chance that this could happen if the populations are indeed the same, then the test concludes that there is a hot spot comprised of k samples from the area of interest.

- In the event that none of the above quantitative statistical tests yielded a definite "yes" or "no" decision, a test of proportions was used to determine if the percentage of positively detected results was greater in the site data versus the background data. When only a very small portion of results is positive detections (less than 10 percent), this test is recommended (EPA, 1996a, 1989b). The test is routinely applied using a normal distribution approximation to the probability that site is above background but is not considered valid when fewer than five positive detections are reported in either site or background.

- As recommended (EPA, 1996a, 1992a, 1989b), quantitative statistical tests were preceded by data analysis to evaluate the distributional shape for both positive and nondetected data, of which quantile plots or tables are one recommended (and efficient) approach. This data analysis is required because multiple detection limits bias or invalidate the conclusions of common statistical tests. For each chemical in each risk group, a quantile (percentile) range evaluation was required to compare the number and magnitude of site and background nondetects. In particular, some of the above tests do not tolerate any non-detects above a certain magnitude or portion of the total. In the case of the Mann-Whitney test, careful quantitative evaluation was used to determine if the site and background populations exhibited the same distributional spread of non-detected results and to determine if the Gehan's test, a more robust test, should be used.

6.2.3 Identification of COPCs

The selection of COPCs was based on various aspects of chemical concentration, occurrence, distribution, and toxicity. COPCs were selected to represent site contamination and to provide the framework for the quantitative HHRA. The COPC selection protocols are defined in Table 6-1. Constituents were screened against background data as outlined in Section 6.2.2 and also against EPA Region III residential risk-based screening concentrations (RBCs).

TABLE 6-1
SUMMARY OF COPC SELECTION CRITERIA, AREA A SURFACE SOIL AND SUBSURFACE SOIL
NAWC WARMINSTER, PENNSYLVANIA

COPC Selection Protocol	*Definition*	Decision Result #1	Decision Result #2	Notes
Essential Nutrients	Eliminate essential nutrients (calcium, chloride, magnesium, potassium, and sodium) as COPCs.	Eliminate essential nutrients as COPCs.	Eliminate essential nutrients as COPCs.	Essential nutrients that are present at elevated concentrations will be noted in the qualitative HHRA.
Background Screening (Applicable for Surface and Subsurface Soil Only)	Compare inorganic contaminants in surface and subsurface soil to background data set.	If a surface and/or subsurface soil inorganic contaminant is within the range of background, eliminate the chemical as COPC.	If statistical tests show surface and/or subsurface inorganic contaminant levels exceed background check Frequency of Detection.	Background screening is only applicable for surface and subsurface soil inorganic contaminants. Organic contaminants are subject to a check for Frequency of Detection.
Frequency of Detection	Compare frequency of positive detections relative to total number of usable results to determine if a substance was detected in greater than 5 percent of samples [Applicable only if the number of samples collected in each media of consideration was >= 20].	If frequency of detection is less than 5 percent and the number of samples collected was >=20, eliminate the chemical as a COPC.	If frequency of detection is greater than 5 percent, do a Toxicity Screen.	Frequency of detection screening applies to all organic and inorganic contaminants. Contaminants detected in less than 5 percent of samples are eliminated from consideration. This screen could miss potential "Hot Spots", *however, any potential "Hot Spots" were* eliminated during the removal actions at the site.
Toxicity Screen vs. RBC	Compare maximum concentrations of inorganic substances (only those that exceed background) and organic contaminants in surface and subsurface soil to Risk Based Screening Levels (RBCs).* Compare maximum concentrations of inorganic and organic substances substances in sediment and surface water to Risk Based Screening Levels (RBCs).**	If maximum concentration of contaminant is less than the applicable RBC; eliminate the contaminant as a COPC.	If the maximum concentration of a contaminant exceeds the applicable RBC, the contaminant is selected as a COPC	Chemicals that are selected as COPCs will be evaluated quantitatively in this HHRA. NOTE: The RBC for hexavalent chromium (Cr VI) is used in this HHRA because speciation data (Cr VI vs. Cr III) were not available for soil samples.
Lead	Compare maximum concentrations of lead in surface and subsurface soil and sediment to a value of 400 mg/kg (EPA, 1994).*** Compare maximum concentrations of lead in surface water *to a value of 15 ug/L (EPA, 1996d).****	If maximum concentration of lead in soil or sediment is less than 400 mg/kg and/or lead in surface water is less than 15 ug/L eliminate lead as a COPC.	If maximum concentration of lead in soil or sediment exceeds 400 mg/kg and/or lead in surface water exceeds 15 ug/L select lead as a COPC.	If lead is selected as a COPC, then risks are evaluated using the Integrated Exposure Uptake Biokinetic model to assess potential blood lead levels in exposed children.

* Risk-Based Concentrations (RBCs; EPA 1999b) are chemical-specific benchmark criteria, prepared by EPA Region III, which represent the concentration of a substance that is estimated to yield a lifetime cancer risk of 1E-06 or a noncarcinogenic hazard quotient (HQ) of 1. RBCs are calculated assuming default exposure assumptions for soil ingestion for a lifetime resident (child plus adult exposure). Those RBCs which are based on non-cancer toxicity are first divided by 10 before being used for screening. (This step adds a safety factor in case more than one contaminant is present that might cause an additive risk of adverse effects.)

** Risk-Based Concentrations (RBCs; EPA 1999b) are chemical-specific benchmark criteria, prepared by EPA Region III, which represent the concentration of a substance that is estimated to yield a lifetime cancer risk of 1E-06 or a noncarcinogenic hazard quotient (HQ) of 1. RBCs are calculated assuming default exposure assumptions for soil ingestion (for sediment screening) and drinking water ingestion (for surface water ingestion) for a lifetime resident (child plus adult exposure). Those RBCs which are based on non-cancer toxicity toxicity are first divided by 10 before being used for screening. (This step adds a safety factor in case more than one contaminant is present that might cause an additive risk of adverse effects.)

*** The lead screening value was developed by the EPA (1994a) Office of Solid Waste and Emergency Response (OSWER). It is not an automatic cleanup goal but rather a level above which there is sufficient concern to merit additional site-specific evaluation of risks.

**** The lead screening value was developed by the EPA (1996d). It is not an automatic cleanup goal but rather a drinking water action level above which there is sufficient concern to merit additional site-specific evaluation of risks.

The on-base portion of Area A was divided into four specific sites: Site 1, Site 2, Site 3, and the Impoundment Area. Following the removal action, there were no COPCs remaining in Site 1 surface soil that exceeded residential screening criteria and exceeded background for inorganics based on statistical tests. COPCs were identified in Site 1 subsurface soil, Site 2 surface and subsurface soils, Site 3 surface and subsurface soils, and subsurface soils in the Impoundment Area. These COPCs were carried through the RR/TE process for the hypothetical future residential child scenario.

Identified COPCs for each site within Area A were then rescreened against EPA Region III industrial RBCs to determine COPCs to be carried through the RR/TE process for the industrial/commercial worker scenario.

Four media (surface soil, subsurface soil, off-base sediment, and off-base surface water) were evaluated for Area A human health risks. The results of the analysis of Area A post-removal soil samples are summarized in the occurrence and distribution tables for background soil [Section 2.2.7 - soils that were collected from various locations at NAWC Warminster (Figure 2-12) that are considered unaffected by past site-related activities; all surface and subsurface background samples were pooled together and used as background for any site-specific surface or subsurface data set], (2) surface soil, and (3) subsurface soil. For off-base sediment and off-base surface water, occurrence and distribution tables were prepared for those samples that were collected between 1989 and 1995. No post-removal sediment or surface water sample results were included in these tables. These tables contain statistics including frequency of detection, range of positive detection, and location of maximum detection.

Subsets of the post-removal surface soil, post-removal subsurface soil, sediment, and surface water databases (Appendix A) were evaluated by including only those chemicals detected at least once in each medium at a suspected source concern. Concentrations of inorganic and/or organic constituents detected in surface soil, subsurface soil, sediment, surface water (total and dissolved inorganics), and sediment and results of background analysis are presented in the following tables:

- Site 1 surface soil – Table 4-3 (no COPCs post-removal)
- Site 1 subsurface soil – Table 4-6
- Site 2 surface soil – Table 4-9
- Site 2 subsurface soil – Table 4-12
- Site 3 surface soil – Table 4-15
- Site 3 subsurface soil – Table 4-18
- Impoundment area subsurface soil – Table 6-21
- Off-base sediment – Tables 4-25 and 4-26
- Off-base surface water – Tables 4-22 and 4-23 (total/dissolved inorganics), and 4-24 (organics)

Essential nutrients (iron, magnesium, potassium, and sodium) were not considered COPCs and were not evaluated, and therefore are not discussed further.

6.2.3.1 Surface Soil COPC Selection

Section 4.0 discusses the results of sampling surface soils at Area A. COPCs in surface soil for residential receptors (using the protocols established in Table 6-1) are listed in Table 6-2 for Site 2, in Table 6-3 for Site 3, and in the residential risk ratio summary table for surface soil (Table 6-4). COPCs in surface soil for industrial/commercial receptors for these areas are listed in the corresponding risk ratio summary table for surface soil (Table 6-5). No COPCs were identified for Site 1 surface soil. In addition, surface soil samples were not collected from the Impoundment Area.

6.2.3.2 Subsurface Soil COPC Selection

Section 4.0 presents the results of sampling subsurface soils at Area A. COPCs in subsurface soil for residential receptors are listed in Table 6-6 for Site 1, in Table 6-7 for Site 2, in Table 6-8 for Site 3, in Table 6-9 for the Impoundment Area, and in the residential risk ratio summary table for subsurface soil (Table 6-10). COPCs in subsurface soil for industrial/commercial receptors are listed in the corresponding risk ratio summary table for subsurface soil (Table 6-11).

6.2.3.3 Surface Water COPC Selection

Potential COPCs for surface water were chosen based on various aspects of their occurrence and distribution, mobility, persistence, and toxicity. These chemicals are selected to represent site contamination and will provide the framework for the quantitative risk assessment. Briefly, comparisons of site-related inorganic concentrations of chemicals detected in surface water were made to appropriate background concentrations and within these chemicals were essential nutrients or minerals. All organics detected in surface water were selected as COCs.

Metals were detected in downstream surface water. The chemicals that were positively detected in surface water in Area A (Tables 4-22, 4-23, and 4-24) and selected as COPCs are presented below:

- 1,1-DCA
- 2-Butanone
- 4,4'-DDD
- 4,4'-DDT
- Benz(a)anthracene
- Benzo(b)fluoranthene
- Chrysene
- Diethylphthalate
- Fluoranthene
- Pyrene
- Benzene
- Bromomethane
- Carbon Disulfide
- Chloroethane
- Chloromethane
- Di-n-octylphthalate
- PCE
- TCE

TABLE 6-2
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Site 2

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	142	J	19800		MG/KG	SS-02-63	20/20		19800	N	7800	N	N	BKG
7440-36-0	ANTIMONY	0.19	J	10.8	J	MG/KG	SS-02-42	24/46	0.2 - 8.8	10.8	N	3.1	N	N	BKG
7440-38-2	ARSENIC	0.88		13.1		MG/KG	SS-02-03	20/20		13.1	N	0.43	C	N	BKG
7440-39-3	BARIUM	4.4	J	452	J	MG/KG	SS-02-07-MAX	20/20		452	Y	550	N	N	BSL
7440-41-7	BERYLLIUM	0.63	J	1.4		MG/KG	SS-02-16-MAX	19/20	0.1	1.4	N	16	N	N	BKG
7440-43-9	**CADMIUM**	0.09		20.3	J	MG/KG	SS-02-26	36/48	0.03 - 2.8	20.3	Y	3.9	N	Y	ASL
7440-70-2	CALCIUM	1050		215000		MG/KG	SS-02-56	20/20		215000	Y		N	N	NUT
7440-47-3	**CHROMIUM**	1.1		133		MG/KG	SS-02-05-MAX	24/24		133	Y	23	N	Y	ASL
7440-48-4	COBALT	0.74	J	14.5		MG/KG	SS-02-06	20/20		14.5	N	470	N	N	BSL
7440-50-8	**COPPER**	5.7		1410		MG/KG	SS-02-22	44/44		1410	Y	310	N	Y	ASL
7439-89-6	IRON	2360	J	38000		MG/KG	SS-02-07-MAX	20/20		38000	N	2300	N	N	BKG
7439-92-1	**LEAD**	8	J	994	J	MG/KG	SS-02-22	48/48		994	Y	400	C	Y	ASL
7439-95-4	MAGNESIUM	1900		135000		MG/KG	SS-02-56	20/20		135000	Y		N	N	NUT
7439-96-5	MANGANESE	169	J	2080		MG/KG	SS-02-05-MAX	20/20		2080	N	160	N	N	BKG
7439-97-6	MERCURY	0.18	J	1.1	J	MG/KG	SS-02-14	8/20	0.04 - 0.25	1.1	Y	2.3	N	N	BSL
7440-02-0	NICKEL	4.9		47		MG/KG	SS-02-07-MAX	11/20	11.4 - 25.4	47	Y	160	N	N	BSL
7440-09-7	POTASSIUM	684		2590		MG/KG	SS-02-18	19/20	57.2	2590	N		N	N	NUT
7782-49-2	SELENIUM	0.89	J	1.6	J	MG/KG	SS-02-07-MAX	3/18	0.33 - 0.85	1.6	Y	39	N	N	BSL
7440-22-4	**SILVER**	0.14	J	58.4		MG/KG	SS-02-07-MAX	25/43	0.04 - 2.3	58.4	Y	39	N	Y	ASL
7440-23-5	SODIUM	84.8		1870	J	MG/KG	SS-02-14	12/20	78.5 - 242	1870	Y		N	N	NUT
7440-28-0	**THALLIUM**	0.81	J	1.4		MG/KG	SS-02-07-MAX	6/24	0.39 - 1.1	1.4	Y	0.55	N	Y	ASL
7440-62-2	**VANADIUM**	24.1		119		MG/KG	SS-02-05-MAX	20/20		119	Y	55	N	Y	ASL
7440-66-6	**ZINC**	23		4800		MG/KG	SS-02-22	44/44		4800	Y	2300	N	Y	ASL
91-57-6	2-METHYLNAPHTHALENE	46	J	21000	J	UG/KG	SS-02-56	2/20	340 - 1700	21000	N/A	160000	N	N	BSL
83-32-9	ACENAPHTHENE	43	J	180	J	UG/KG	SS-02-06	4/20	340 - 33000	180	N/A	470000	N	N	BSL
208-96-8	ACENAPHTHYLENE	44	J	440	J	UG/KG	SS-02-07-MAX	6/20	340 - 33000	440	N/A	160000	N	N	BSL
120-12-7	ANTHRACENE	51	J	640	J	UG/KG	SS-02-05-MAX	12/20	360 - 33000	640	N/A	2300000	N	N	BSL
56-55-3	**BENZO(A)ANTHRACENE**	190	J	3300		UG/KG	SS-02-05-MAX	16/23	360 - 33000	3300	N/A	870	C	Y	ASL
50-32-8	**BENZO(A)PYRENE**	47	J	3400		UG/KG	SS-02-05-MAX	17/24	360 - 33000	3400	N/A	87	C	Y	ASL
205-99-2	**BENZO(B)FLUORANTHENE**	300	J	5300		UG/KG	SS-02-05-MAX	14/20	360 - 33000	5300	N/A	870	C	Y	ASL
191-24-2	BENZO(G,H,I)PERYLENE	55	J	4400	J	UG/KG	SS-02-39	23/38	340 - 33000	4400	N/A	160000	N	N	BSL
207-08-9	BENZO(K)FLUORANTHENE	110	J	1800		UG/KG	SS-02-05-MAX	14/20	360 - 33000	1800	N/A	8700	C	N	BSL
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	1000		1800		UG/KG	SS-02-70-MAX	2/20	75 - 33000	1800	N/A	46000	C	N	BSL
86-74-8	CARBAZOLE	48	J	560	J	UG/KG	SS-02-05-MAX	9/20	340 - 33000	560	N/A	32000	C	N	BSL
218-01-9	CHRYSENE	260	J	3300		UG/KG	SS-02-05-MAX	14/20	360 - 33000	3300	N/A	87000	C	N	BSL
53-70-3	DIBENZO(A,H)ANTHRACENE	43	J	61	J	UG/KG	SS-02-02	2/20	340 - 33000	61	N/A	87	C	N	BSL
132-64-9	DIBENZOFURAN	37	J	470	J	UG/KG	SS-02-05-MAX	7/20	340 - 33000	470	N/A	31000	N	N	BSL
84-74-2	DI-N-BUTYL PHTHALATE	41	J	73	J	UG/KG	SS-02-02, SS-02-06	4/20	340 - 33000	73	N/A	780000	N	N	BSL
206-44-0	FLUORANTHENE	390		6200		UG/KG	SS-02-05-MAX	14/20	360 - 33000	6200	N/A	310000	N	N	BSL
86-73-7	FLUORENE	58	J	250	J	UG/KG	SS-02-05-MAX	6/20	340 - 33000	250	N/A	310000	N	N	BSL
193-39-5	**INDENO(1,2,3-CD)PYRENE**	37	J	5000	J	UG/KG	SS-02-39	31/41	360 - 33000	5000	N/A	870	C	Y	ASL
91-20-3	NAPHTHALENE	52	J	52	J	UG/KG	SS-02-06	1/20	340 - 33000	52	N/A	160000	N	N	BSL
85-01-8	PHENANTHRENE	120	J	3700		UG/KG	SS-02-05-MAX	14/20	360 - 33000	3700	N/A	160000	N	N	BSL
129-00-0	PYRENE	290	J	4600		UG/KG	SS-02-05-MAX	14/20	360 - 33000	4600	N/A	230000	N	N	BSL
108-88-3	TOLUENE	2	J	2	J	UG/KG	SS-02-03	1/12	10 - 31	2	N/A	1600000	N	N	BSL
72-54-8	4,4'-DDD	19	J	19	J	UG/KG	SS-02-56	1/12	3.4 - 4.1	19	N/A	2700	C	N	BSL
72-55-9	4,4'-DDE	7.9	J	7.9	J	UG/KG	SS-02-01	1/12	3.4 - 21	7.9	N/A	1900	C	N	BSL
50-29-3	4,4'-DDT	4.2	J	23	J	UG/KG	SS-02-01	4/12	3.5 - 21	23	N/A	1900	C	N	BSL
5103-71-9	ALPHA-CHLORDANE	4.6	J	160		UG/KG	SS-02-69	2/12	1.8 - 21	160	N/A	1800	C	N	BSL

4/24/00

TABLE 6-2
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Site 2

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
11097-69-1	**AROCLOR-1254**	11	J	3700		UG/KG	SS-02-69	12/20	35 - 41	3700	N/A	320	C	Y	ASL
11096-82-5	AROCLOR-1260	110	J	110	J	UG/KG	SS-02-08	1/20	34 - 180	110	N/A	320	C	N	BSL
60-57-1	DIELDRIN	32	J	32	J	UG/KG	SS-02-69	1/12	3.4 - 21	32	N/A	40	C	N	BSL
72-20-8	ENDRIN	5.8	J	370	J	UG/KG	SS-02-69	4/12	3.5 - 21	370	N/A	2300	N	N	BSL
58-89-9	GAMMA-BHC (LINDANE)	2.3	J	5	J	UG/KG	SS-02-06	5/12	1.8 - 21	5	N/A	490	C	N	BSL
5103-74-2	GAMMA-CHLORDANE	11	J	11	J	UG/KG	SS-02-69	1/12	1.8 - 21	11	N/A	1800	C	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Solid Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason:
Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason:
Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

4/24/00

TABLE 6-3
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 3 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Site 3

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	7510		12800		MG/KG	SS-03-02	5/5	0	12800	N	7800	N	N	BKG
7440-38-2	ARSENIC	3.5	J	7.9		MG/KG	SS-03-06	5/5	0	7.9	N	0.43	C	N	BKG
7440-39-3	BARIUM	66.7		99		MG/KG	SS-03-06	5/5	0	99	Y	550	N	N	BSL
7440-41-7	BERYLLIUM	0.82		0.97		MG/KG	SS-03-06	5/5	0	0.97	N	16	N	N	BSL
7440-70-2	CALCIUM	4060		30700		MG/KG	SS-03-06	5/5	0	30700	Y		N	N	NUT
7440-47-3	**CHROMIUM**	16.2		36.8		MG/KG	SS-03-05	5/5	0	36.8	Y	23	N	Y	ASL
7440-48-4	COBALT	7.9		11.7		MG/KG	SS-03-06	5/5	0	11.7	N	470	N	N	BSL
7440-50-8	COPPER	11		42.3	J	MG/KG	SS-03-05	5/5	0	42.3	Y	310	N	N	BSL
57-12-5	CYANIDE	0.51	J	0.51	J	MG/KG	SS-03-02	1/2	0.52	0.51	Y	160	N	N	BSL
7439-89-6	IRON	14800		28600		MG/KG	SS-03-06	5/5	0	28600	N	2300	N	N	BKG
7439-92-1	LEAD	18.2		30.4		MG/KG	SS-03-02	5/5	0	30.4	Y	400	C	N	BSL
7439-95-4	MAGNESIUM	3280		12300		MG/KG	SS-03-06	5/5	0	12300	Y		N	N	NUT
7439-96-5	**MANGANESE**	401		1180	J	MG/KG	SS-03-01	5/5	0	1180	Y	160	N	Y	ASL
7440-02-0	NICKEL	10.5	J	21.5		MG/KG	SS-03-06	4/5	14.3	21.5	Y	160	N	N	BSL
7440-09-7	POTASSIUM	699		2510		MG/KG	SS-03-02	5/5	0	2510	Y		N	N	NUT
7440-23-5	SODIUM	147		3620		MG/KG	SS-03-02	4/5	128	3620	Y		N	N	NUT
7440-28-0	**THALLIUM**	1.1	J	1.1	J	MG/KG	SS-03-02	1/5	0.55 - 0.95	1.1	Y	0.55	N	Y	ASL
7440-62-2	VANADIUM	22.7		50.7		MG/KG	SS-03-06	5/5	0	50.7	Y	55	N	N	BSL
7440-66-6	ZINC	34.5		167		MG/KG	SS-03-05	5/5	0	167	Y	2300	N	N	BSL
208-96-8	ACENAPHTHYLENE	33	J	120	J	UG/KG	SS-03-07	5/8	340 - 3900	120	N/A	160000	N	N	BSL
120-12-7	ANTHRACENE	65	J	220	J	UG/KG	SS-03-08	9/13	340 - 3900	220	N/A	2300000	N	N	BSL
56-55-3	**BENZO(A)ANTHRACENE**	56	J	1200		UG/KG	SS-03-08	13/13	0	1200	N/A	870	C	Y	ASL
50-32-8	**BENZO(A)PYRENE**	52	J	1400		UG/KG	SS-03-15	11/13	3800 - 3900	1400	N/A	87	C	Y	ASL
205-99-2	**BENZO(B)FLUORANTHENE**	130	J	1300		UG/KG	SS-03-08	8/8	0	1300	N/A	870	C	Y	ASL
191-24-2	BENZO(G,H,I)PERYLENE	59	J	320	J	UG/KG	SS-03-08	6/8	3800 - 3900	320	N/A	160000	N	N	BSL
207-08-9	BENZO(K)FLUORANTHENE	79	J	1000		UG/KG	SS-03-08	5/8	340 - 3900	1000	N/A	8700	C	N	BSL
218-01-9	CHRYSENE	79	J	1200	J	UG/KG	SS-03-05	8/8	0	1200	N/A	87000	C	N	BSL
53-70-3	**DIBENZO(A,H)ANTHRACENE**	35	J	99	J	UG/KG	SS-03-08	3/8	340 - 3900	99	N/A	87	C	Y	ASL
206-44-0	FLUORANTHENE	120	J	3300		UG/KG	SS-03-15	11/13	3800 - 3900	3300	N/A	310000	N	N	BSL
86-73-7	FLUORENE	28	J	41	J	UG/KG	SS-03-07	2/8	340 - 3900	41	N/A	310000	N	N	BSL
193-39-5	INDENO(1,2,3-CD)PYRENE	43	J	380	J	UG/KG	SS-03-08	6/8	3800 - 3900	380	N/A	870	C	N	BSL
85-01-8	PHENANTHRENE	40	J	1100	J	UG/KG	SS-03-05	7/8	3900	1100	N/A	160000	N	N	BSL
129-00-0	PYRENE	100	J	1800	J	UG/KG	SS-03-05	8/8	0	1800	N/A	230000	N	N	BSL
79-34-5	1,1,2,2-TETRACHLOROETHANE	1	J	1	J	UG/KG	SS-03-06	1/1	0	1	N/A	25000	C	N	BSL
74-83-9	BROMOMETHANE	21		21		UG/KG	SS-03-06	1/1	0	21	N/A			N	
50-29-3	4,4'-DDT	7.1	J	15	J	UG/KG	SS-03-03	2/4	3.5 - 3.9	15	N/A	1900	C	N	BSL
58-89-9	GAMMA-BHC (LINDANE)	1.9	J	2.5	J	UG/KG	SS-03-03	2/4	1.8 - 1.9	2.5	N/A	490	C	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Solid Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason: Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

4/24/00

TABLE 6-4
RESIDENTIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 2	PAH(s)					
	BENZ[A]ANTHRACENE	3.30	N/A	8.75E-01	N/A	3.77E-06
	BENZO[A]PYRENE	3.40	N/A	8.75E-02	N/A	3.88E-05
	BENZO[B]FLUORANTHENE	5.30	N/A	8.75E-01	N/A	6.06E-06
	INDENO[1,2,3-CD]PYRENE	5.00	N/A	8.75E-01	N/A	5.71E-06
	PESTICIDES					
	AROCLOR-1254	3.70	3.19E-01	3.19E-01	11.59	1.16E-05
	INORGANICS					
	CADMIUM	20.30	3.90E+01	N/A	0.52	N/A
	CHROMIUM VI	133.00	2.30E+02	N/A	0.58	N/A
	COPPER	1410.00	3.13E+03	N/A	0.45	N/A
	LEAD	994 J	N/A	N/A	N/A	N/A
	SILVER	58.40	3.91E+02	N/A	0.15	N/A
	THALLIUM	1.40	5.48E+00	N/A	0.26	N/A
	VANADIUM	119.00	5.48E+02	N/A	0.22	N/A
	ZINC	4800.00	2.35E+04	N/A	0.20	N/A
				TOTAL:	**13.97**	**6.59E-05**
Site 3	PAH(s)					
	BENZ[A]ANTHRACENE	1.20	N/A	8.75E-01	N/A	1.37E-06
	BENZO[A]PYRENE	1.40	N/A	8.75E-02	N/A	1.60E-05
	BENZO[B]FLUORANTHENE	1.30	N/A	8.75E-01	N/A	1.49E-06
	DIBENZ[A,H]ANTHRACENE	0.10	N/A	8.75E-02	N/A	1.13E-06

TABLE 6-4
RESIDENTIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 3	INORGANICS					
	CHROMIUM VI	36.80	2.35E+02	N/A	0.16	N/A
	MANGANESE	1180.00	1.56E+03	N/A	0.75	N/A
	THALLIUM	1.10	5.48E+00	N/A	0.20	N/A
				TOTAL:	**1.11**	**2.00E-05**

TABLE 6-5
INDUSTRIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 2	PAH(s)					
	BENZ[A]ANTHRACENE	3.30	N/A	7.84E+00	N/A	4.21E-07
	BENZO[A]PYRENE	3.40	N/A	7.84E-01	N/A	4.34E-06
	BENZO[B]FLUORANTHENE	5.30	N/A	7.84E+00	N/A	6.76E-07
	INDENO[1,2,3-C,D]PYRENE	5.00	N/A	7.84E+00	N/A	6.38E-07
	PESTICIDES					
	AROCLOR-1254	3.70	2.86E+00	2.86E+00	1.29	1.29E-06
	INORGANICS					
	CADMIUM	20.30	1.00E+03	N/A	0.02	N/A
	CHROMIUM VI	133.00	6.13E+03	N/A	0.02	N/A
	COPPER	1410.00	8.20E+04	N/A	0.02	N/A
	SILVER	58.40	1.00E+04	N/A	0.01	N/A
	THALLIUM	1.40	1.40E+02	N/A	0.01	N/A
	VANADIUM	119.00	1.40E+04	N/A	0.01	N/A
	ZINC	4800.00	6.10E+05	N/A	0.01	N/A
				TOTAL:	**1.39**	**7.37E-06**
Site 3	PAH(s)					
	BENZO[A]PYRENE	1.40	N/A	7.84E-01	N/A	1.79E-06
				TOTAL:	**0.00**	**1.79E-06**

TABLE 6-6
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 1 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe:
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Site 1

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	5580		33500		MG/KG	SB-01-05	17/17		33500	N	7800	N	N	BKG
7440-36-0	**ANTIMONY**	0.31		15.2	J	MG/KG	SB-01-48	9/30	0.17 - 19.2	15.2	N	3.1	N	Y	ASL
7440-38-2	ARSENIC	1.3		25.5		MG/KG	SB-01-14	16/17	1.8	25.5	N	0.43	C	N	BKG
7440-39-3	BARIUM	26.4		210		MG/KG	SB-01-02	17/17		210	N	550	N	N	BSL
7440-41-7	BERYLLIUM	0.41		3.1		MG/KG	SB-01-14	15/17	0.73 - 1.2	3.1	Y	16	N	N	BSL
7440-43-9	**CADMIUM**	0.05		61.4		MG/KG	SB-01-25	23/40	0.05 - 1	61.4	Y	7.8	N	Y	ASL
7440-70-2	CALCIUM	314		53400		MG/KG	SB-01-25	17/17		53400	Y	N/A	N	N	NUT
7440-47-3	**CHROMIUM**	7		4600		MG/KG	SB-01-48	38/39	9.7	4600	Y	23	N	Y	ASL
7440-48-4	COBALT	7.1		66.1		MG/KG	SB-01-25	16/17	4.5	66.1	Y	470	N	N	BSL
7440-50-8	COPPER	2.5		299	J	MG/KG	SB-01-28	17/17		299	Y	310	N	N	BSL
57-12-5	CYANIDE	1.6		1.6		MG/KG	SB-01-05	1/5	0.61 - 1.2	1.6	Y	160	N	N	BSL
7439-89-6	**IRON**	9560		251000		MG/KG	SB-01-25	17/17		251000	Y	2300	N	N	ASL
7439-92-1	LEAD	2.1		135		MG/KG	SB-01-25	24/24		135	Y	400	C	N	BSL
7439-95-4	MAGNESIUM	380		5890		MG/KG	SB-01-16	17/17		5890	Y	N/A	N	N	NUT
7439-96-5	**MANGANESE**	230		2630		MG/KG	SB-01-02	17/17		2630	Y	160	N	Y	ASL
7439-97-6	**MERCURY**	0.1		6.8		MG/KG	SB-01-25	7/17	0.05 - 0.12	6.8	Y	2.3	N	Y	ASL
7440-02-0	NICKEL	3.1		87.9		MG/KG	SB-01-25	14/17	10.2 - 18	87.9	Y	160	N	N	BSL
7440-09-7	POTASSIUM	320		4600		MG/KG	SB-01-21	13/17	190 - 300	4600	Y	N/A	N	N	NUT
7782-49-2	SELENIUM	0.88		3.3		MG/KG	SB-01-25	6/17	0.3 - 1.2	3.3	Y	39	N	N	BSL
7440-22-4	**SILVER**	0.67		360		MG/KG	SB-01-25	11/17	0.68 - 1.1	360	Y	39	N	Y	ASL
7440-23-5	SODIUM	17.2		707		MG/KG	SB-01-25	15/17	59.9 - 65.1	707	Y	N/A	N	N	NUT
7440-28-0	**THALLIUM**	0.4		1.7		MG/KG	SB-01-25	10/24	0.37 - 1.2	1.7	Y	0.55	N	Y	ASL
7440-62-2	VANADIUM	13.8		66.6		MG/KG	SB-01-05	17/17		66.6	N	55	N	N	BKG
7440-66-6	ZINC	11.8		451		MG/KG	SB-01-25	17/17		451	Y	2300	N	N	BSL
78-93-3	2-BUTANONE	4.8	J	4.8	J	UG/KG	SB-01-30	1/6	12 - 13	4.8	N/A	4700000	N	N	BSL
72-54-8	4,4'-DDD	55	J	55	J	UG/KG	SB-01-06-MAX	1/2	4.1	55	N/A	2700	C	N	BSL
72-55-9	4,4'-DDE	4.3		12	J	UG/KG	SB-01-06-MAX	2/2		12	N/A	1900	C	N	BSL
108-10-1	4-METHYL-2-PENTANONE	1.6	J	1.6	J	UG/KG	SB-01-30	1/6	12 - 13	1.6	N/A	630000	N	N	BSL
11097-69-1	AROCLOR-1254	41	J	41	J	UG/KG	SB-01-06-MAX	1/8	37 - 41	41	N/A	320	C	N	BSL
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	40	J	40	J	UG/KG	SB-01-06-MAX	1/8	370 - 410	40	N/A	46000	C	N	BSL
72-20-8	ENDRIN	4.8	J	4.8	J	UG/KG	SB-01-06-MAX	1/2	4.1	4.8	N/A	2300	N	N	BSL
108-88-3	TOLUENE	2.9	J	2.9	J	UG/KG	SB-01-30	1/6	2 - 13	2.9	N/A	1600000	N	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Solid Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason: Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

4/21/00

TABLE 6-7
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Site 2

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	5210		133000		MG/KG	TP10-0207	66/66		133000	Y	7800	N	Y	ASL
7440-36-0	ANTIMONY	0.37	L	90.5	L	MG/KG	SB-02-16	36/76	0.32 - 12.8	90.5	Y	3.1	N	Y	ASL
7440-38-2	ARSENIC	0.85	L	19.6		MG/KG	SB-02-09	60/66	1.1 - 3	19.6	Y	0.43	C	Y	ASL
7440-39-3	BARIUM	21.6		719		MG/KG	SB-02-28-MAX	66/66		719	Y	550	N	Y	ASL
7440-41-7	BERYLLIUM	0.25		8.2		MG/KG	SB-02-42	56/66	0.48 - 1.5	8.2	Y	16	N	N	BSL
7440-43-9	CADMIUM	0.14	K	293		MG/KG	SB-02-27	44/93	0.05 - 3.8	293	Y	3.9	N	Y	ASL
7440-70-2	CALCIUM	366	J	74000		MG/KG	SB-02-15	65/66	643	74000	Y		N	N	NUT
7440-47-3	CHROMIUM	4	K	3840		MG/KG	SB-02-16	66/66		3840	Y	23	N	Y	ASL
7440-48-4	COBALT	3.5		24.6		MG/KG	SB-02-08	65/66	7.2	24.6	Y	470	N	N	BSL
7440-50-8	COPPER	4.6	J	7980		MG/KG	SB-02-75-MAX	79/80	0.99	7980	Y	310	N	Y	ASL
57-12-5	CYANIDE	0.93		20.4		MG/KG	SB-02-16	4/46	0.53 - 3.2	20.4	Y	160	N	N	BSL
7439-89-6	IRON	4000		103000		MG/KG	SB-02-08	66/66		103000	Y	2300	N	Y	ASL
7439-92-1	LEAD	1.5	J	2060	J	MG/KG	SB-02-71	86/93	9.1 - 43.9	2060	Y	400	C	Y	ASL
7439-95-4	MAGNESIUM	680		29900		MG/KG	SB-02-32	65/66	1720	29900	Y		N	N	NUT
7439-96-5	MANGANESE	127		1760		MG/KG	SB-02-28-MAX	66/66		1760	Y	160	N	Y	ASL
7439-97-6	MERCURY	0.04	L	0.98		MG/KG	SB-02-17	25/66	0.03 - 0.13	0.98	Y	2.3	N	N	BSL
7440-02-0	NICKEL	3.1	L	143		MG/KG	SB-02-42	57/66	10.9 - 18.3	143	Y	160	N	Y	ASL
7440-09-7	POTASSIUM	110		2690		MG/KG	SB-02-37	60/66	345 - 785	2690	Y		N	N	NUT
7782-49-2	SELENIUM	0.78	J	7.3	J	MG/KG	TP10-0207	4/60	0.34 - 1.2	7.3	Y	39	N	N	BSL
7440-22-4	SILVER	0.11	L	317		MG/KG	SB-02-70-MAX	30/81	0.05 - 2.2	317	Y	39	N	Y	ASL
7440-23-5	SODIUM	45		2910		MG/KG	TP02-02-02	33/66	20.8 - 460	2910	Y		N	N	NUT
7440-28-0	THALLIUM	0.69	J	0.69	J	MG/KG	TP10-0207	1/66	0.38 - 12.9	0.69	Y	0.55	N	Y	ASL
7440-62-2	VANADIUM	5.7		586		MG/KG	SB-02-42	66/66		586	Y	55	N	Y	ASL
7440-66-6	ZINC	5.2	J	5640		MG/KG	SB-02-42	80/80		5640	Y	2300	N	Y	ASL
75-34-3	1,1-DICHLOROETHANE	16		16		UG/KG	SB-02-35	1/53	4 - 1500	16	N/A	780000	N	N	BSL
540-59-0	1,2-DICHLOROETHENE (TOTAL)	3	J	60		UG/KG	SB-02-12	3/53	5.1 - 1500	60	N/A	70000	N	N	BSL
78-93-3	2-BUTANONE	4.5	J	20	J	UG/KG	SB-02-02	3/53	10 - 1600	20	N/A	4700000	N	N	BSL
591-78-6	2-HEXANONE	1	J	2	J	UG/KG	TP11-0209	2/53	10 - 1500	2	N/A	310000	N	N	BSL
108-10-1	4-METHYL-2-PENTANONE	0.9	J	110		UG/KG	SB-02-31	4/53	11 - 1500	110	N/A	630000	N	N	BSL
67-64-1	ACETONE	49		170		UG/KG	SB-02-10	8/53	1 - 1500	170	N/A	780000	N	N	BSL
71-43-2	BENZENE	1	J	8		UG/KG	TP10-0207	3/53	5 - 1500	8	N/A	22000	C	N	BSL
74-83-9	BROMOMETHANE	360	J	360	J	UG/KG	SB-02-09	1/52	4 - 750	360	N/A	11000	N	N	BSL
75-15-0	CARBON DISULFIDE	2	J	10		UG/KG	TP14-0213	2/53	4 - 1500	10	N/A	780000	N	N	BSL
75-00-3	CHLOROETHANE	3	J	3	J	UG/KG	TP11-0209	1/53	4 - 1500	3	N/A	220000	C	N	BSL
67-66-3	CHLOROFORM	1	J	1	J	UG/KG	TP02-02-02	1/53	1 - 1500	1	N/A	100000	C	N	BSL
74-87-3	CHLOROMETHANE	810	J	810	J	UG/KG	SB-02-09	1/53	4 - 480	810	N/A	49000	C	N	BSL
100-41-4	ETHYLBENZENE	3	J	13	J	UG/KG	SB-02-32	3/53	4 - 1500	13	N/A	780000	N	N	BSL
75-09-2	METHYLENE CHLORIDE	1	J	23	J	UG/KG	SB-02-32	5/53	2 - 1300	23	N/A	85000	C	N	BSL
127-18-4	TETRACHLOROETHENE	2	J	36	J	UG/KG	SB-02-11-MAX	13/53	5.1 - 1500	36	N/A	12000	C	N	BSL
108-88-3	TOLUENE	2	J	150		UG/KG	SB-02-32	6/53	1.6 - 1500	150	N/A	1600000	N	N	BSL
10061-02-6	TRANS-1,3-DICHLOROPROPENE	97.75	J	97.75	J	UG/KG	SB-02-07	1/53	4 - 1500	97.75	N/A	3500	C	N	BSL
79-01-6	TRICHLOROETHENE	1	J	12		UG/KG	SB-02-19	12/53	5.1 - 1500	12	N/A	58000	C	N	BSL
106-46-7	1,4-DICHLOROBENZENE	68	J	68	J	UG/KG	SB-02-07	1/38	190 - 8100	68	N/A	27000	C	N	BSL
91-94-1	3,3'-DICHLOROBENZIDINE	400		400		UG/KG	SB-02-07	1/38	190 - 8100	400	N/A	1400	C	N	BSL
83-32-9	ACENAPHTHENE	75	J	1400		UG/KG	SB-02-53	6/38	190 - 8100	1400	N/A	470000	N	N	BSL
120-12-7	ANTHRACENE	98	J	2200		UG/KG	SB-02-53	10/38	190 - 8100	2200	N/A	2300000	N	N	BSL
56-55-3	BENZO(A)ANTHRACENE	49	J	5200		UG/KG	SB-02-53	21/38	190 - 430	5200	N/A	870	C	Y	ASL
50-32-8	BENZO(A)PYRENE	44	J	3800		UG/KG	SB-02-53	22/39	190 - 430	3800	N/A	87	C	Y	ASL
205-99-2	BENZO(B)FLUORANTHENE	51	J	4900		UG/KG	SB-02-53	21/38	190 - 430	4900	N/A	870	C	Y	ASL
191-24-2	BENZO(G,H,I)PERYLENE	51	J	2100		UG/KG	TP10-0207	19/38	190 - 430	2100	N/A	160000	N	N	BSL
207-08-9	BENZO(K)FLUORANTHENE	23	J	2200		UG/KG	TP10-0207	20/38	190 - 580	2200	N/A	8700	C	N	BSL
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	46	J	2200	J	UG/KG	SB-02-41	6/39	47 - 8100	2200	N/A	46000	C	N	BSL
85-68-7	BUTYL BENZYL PHTHALATE	55		110	J	UG/KG	SB-02-22	3/33	360 - 8100	110	N/A	1600000	N	N	BSL
86-74-8	CARBAZOLE	91	J	1300		UG/KG	SB-02-53	6/38	190 - 8100	1300	N/A	32000	C	N	BSL
218-01-9	CHRYSENE	42	J	4900		UG/KG	SB-02-53	22/38	190 - 430	4900	N/A	87000	C	N	BSL
84-74-2	DI-N-BUTYL PHTHALATE	46	J	4200		UG/KG	SB-02-41	7/38	51 - 8100	4200	N/A	780000	N	N	BSL

4/21/00

TABLE 6-7
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Site 2

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
53-70-3	DIBENZO(A,H)ANTHRACENE	62	J	450		UG/KG	SB-02-53	6/38	190 - 8100	450	N/A	87	C	Y	ASL
132-64-9	DIBENZOFURAN	88	J	570		UG/KG	SB-02-53	5/38	190 - 8100	570	N/A	31000	N	N	BSL
84-66-2	DIETHYL PHTHALATE	48	J	67	J	UG/KG	SB-02-56-MAX	2/38	190 - 8100	67	N/A	6300000	N	N	BSL
206-44-0	FLUORANTHENE	68	J	13000		UG/KG	SB-02-53	22/38	190 - 430	13000	N/A	310000	N	N	BSL
86-73-7	FLUORENE	66	J	1000		UG/KG	SB-02-53	7/38	190 - 8100	1000	N/A	310000	N	N	BSL
193-39-5	INDENO(1,2,3-CD)PYRENE	29	J	2500		UG/KG	TP10-0207	17/38	190 - 8100	2500	N/A	870	C	Y	ASL
91-20-3	NAPHTHALENE	51	J	250	J	UG/KG	SB-02-53	4/38	190 - 8100	250	N/A	160000	N	N	BSL
87-86-5	PENTACHLOROPHENOL	62	J	62	J	UG/KG	SB-02-08	1/38	360 - 20000	62	N/A	5300	C	N	BSL
85-01-8	PHENANTHRENE	43	J	9900		UG/KG	SB-02-53	18/38	190 - 770	9900	N/A	160000	N	N	BSL
129-00-0	PYRENE	42	J	9800		UG/KG	SB-02-53	23/38	190 - 430	9800	N/A	230000	N	N	BSL
309-00-2	ALDRIN	3.6		3.6		UG/KG	SB-02-08	1/40	1.7 - 20	3.6	N/A	38	C	N	BSL
5103-71-9	ALPHA-CHLORDANE	2.9	J	5.9		UG/KG	SB-02-27	2/40	1.7 - 20	5.9	N/A	1800	C	N	BSL
12672-29-6	AROCLOR-1248	110	J	110	J	UG/KG	SB-02-27	1/42	34 - 400	110	N/A	320	C	N	BSL
11097-69-1	AROCLOR-1254	11	J	1150	J	UG/KG	SB-02-07	5/42	34 - 58	1150	N/A	320	C	Y	ASL
11096-82-5	AROCLOR-1260	9	J	1600	J	UG/KG	SB-02-07	7/42	34 - 43	1600	N/A	320	C	Y	ASL
60-57-1	DIELDRIN	4.3	J	5.8	J	UG/KG	SB-02-42	2/40	3.4 - 40	5.8	N/A	40	C	N	BSL
33213-65-9	ENDOSULFAN II	2.4	J	8.5	J	UG/KG	SB-02-27	2/39	3.4 - 5.8	8.5	N/A	47000	N	N	BSL
1031-07-8	ENDOSULFAN SULFATE	9.3	J	9.3	J	UG/KG	TP11-0209	1/40	3.4 - 40	9.3	N/A	47000	N	N	BSL
72-20-8	ENDRIN	2.1	J	20	J	UG/KG	SB-02-27	6/40	3.4 - 40	20	N/A	2300	N	N	BSL
53494-70-5	ENDRIN KETONE	1.2	L	5.5	J	UG/KG	SB-02-27	3/40	3.4 - 40	5.5	N/A	2300	N	N	BSL
58-89-9	GAMMA-BHC (LINDANE)	2.5	J	2.5	J	UG/KG	SB-02-02	1/40	1.7 - 20	2.5	N/A	490	C	N	BSL
5103-74-2	GAMMA-CHLORDANE	2.3	J	3.4	J	UG/KG	SB-02-08	2/38	1.8 - 20	3.4	N/A	1800	C	N	BSL
1024-57-3	HEPTACHLOR EPOXIDE	3.5	J	3.5	J	UG/KG	SB-02-08	1/40	1.7 - 20	3.5	N/A	70	C	N	BSL
18540299	HEXAVALENT CHROMIUM	0.00153	J	0.00359	L	UG/KG	SB-02-24	5/13	.00024 - 0.00	0.00359	N/A	23	N	N	BSL
72-55-9	4,4'-DDE	7.9	J	82	J	UG/KG	SB-02-42	3/40	3.4 - 40	82	N/A	1900	C	N	BSL
50-29-3	4,4'-DDT	1.8	J	150	J	UG/KG	SB-02-42	7/39	3.6 - 40	150	N/A	1900	C	N	BSL
1330-20-7	XYLENES, TOTAL	2.8	J	38	J	UG/KG	SB-02-32	5/53	5.1 - 1500	38	N/A	16000000	N	N	BSL
3268-87-9	OCDD	0.25	J	0.68	J	UG/KG	SB-02-40	4/5	0.28	0.68	N/A	4.3	C	N	BSL
39001-02-0	OCDF	0.25	J	0.25	J	UG/KG	SB-02-42	1/5	0.032 - 0.25	0.25	N/A	4.3	C	N	BSL
72-54-8	4,4'-DDD	2.3	J	45	J	UG/KG	SB-02-08	4/40	3.4 - 40	45	N/A	2700	C	N	BSL
91-57-6	2-METHYLNAPHTHALENE	110	J	360	J	UG/KG	SB-02-33	3/38	190 - 8100	360	N/A	160000	N	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Solid Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason:
Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason:
Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

TABLE 6-8
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Site 3

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	6960	J	29500		MG/KG	TP03-03-06	29/29		29500	N	7800	N	N	BSL
7440-36-0	**ANTIMONY**	0.42	J	16.6		MG/KG	TP03-03-06	9/29	0.33 - 13	16.6	Y	3.1	N	Y	ASL
7440-38-2	**ARSENIC**	1.1		17.6	J	MG/KG	SB-03-11	25/29	2.7 - 5.3	17.6	Y	0.43	C	Y	ASL
7440-39-3	**BARIUM**	50.3		1530		MG/KG	TP03-03-06	28/29	74.7	1530	Y	550	N	Y	ASL
7440-41-7	BERYLLIUM	0.63		3.1		MG/KG	TP02-03-04	25/29	0.51 - 1.2	3.1	Y	16	N	N	BSL
7440-43-9	**CADMIUM**	1.1	J	67.1		MG/KG	TP03-03-06	15/29	0.52 - 3	67.1	Y	3.9	N	Y	ASL
7440-70-2	CALCIUM	600		42500		MG/KG	TP03-03-06	27/29	2090 - 8850	42500	Y			N	NUT
7440-47-3	**CHROMIUM**	13.6		83.4		MG/KG	TP03-03-06	28/29	8.3	83.4	Y	23	N	Y	ASL
7440-48-4	COBALT	4.9		23.4		MG/KG	TP02-03-04	28/29	8.1	23.4	N	470	N	N	BSL
7440-50-8	**COPPER**	5.2		3760		MG/KG	TP03-03-06	28/29	13.1	3760	Y	310	N	Y	ASL
7439-89-6	**IRON**	10900		69500		MG/KG	SB-03-11	29/29		69500	Y	2300	N	Y	ASL
7439-92-1	**LEAD**	5		4570	J	MG/KG	SB-03-22	35/35		4570	Y	400	C	Y	ASL
7439-95-4	MAGNESIUM	1710		15600		MG/KG	SB-03-07	27/29	3300 - 5250	15600	Y			N	NUT
7439-96-5	**MANGANESE**	99.1	J	2330		MG/KG	TP01-03-03	29/29		2330	Y	160	N	Y	ASL
7439-97-6	**MERCURY**	0.15	J	9.7		MG/KG	SB-03-07	16/29	0.05 - 0.12	9.7	Y	2.3	N	Y	ASL
7440-02-0	**NICKEL**	6.6		230		MG/KG	SB-03-11	29/29		230	Y	160	N	Y	ASL
7440-09-7	POTASSIUM	379		3710		MG/KG	TP02-03-04	29/29		3710	N			N	NUT
7782-49-2	SELENIUM	0.54	J	2.9		MG/KG	TP03-03-06	7/29	0.52 - 1.1	2.9	Y	39	N	N	BSL
7440-22-4	**SILVER**	0.96	J	368		MG/KG	TP03-03-06	16/29	0.7 - 2.3	368	Y	39	N	Y	ASL
7440-23-5	SODIUM	48.9		1460		MG/KG	TP03-03-06	28/29	1320	1460	Y			N	NUT
7440-28-0	**THALLIUM**	1.1		1.4	J	MG/KG	SB-03-12	2/29	0.42 - 1.2	1.4	Y	0.55	N	Y	ASL
7440-62-2	**VANADIUM**	8.9		284		MG/KG	SB-03-12	29/29		284	Y	55	N	Y	ASL
7440-66-6	**ZINC**	21.6		9100		MG/KG	TP03-03-06	28/29	41.7	9100	Y	2300	N	Y	ASL
540-59-0	1,2-DICHLOROETHENE (TOTAL)	4	J	4	J	UG/KG	SB-03-23-MAX	1/29	5.8 - 2900	4	N/A	70000	N	N	BSL
78-93-3	2-BUTANONE	5.6	J	1000	J	UG/KG	TP01-03-01	8/29	10 - 2900	1000	N/A	4700000	N	N	BSL
67-64-1	ACETONE	8.4	J	140		UG/KG	TP01-03-02	6/29	11 - 2900	140	N/A	780000	N	N	BSL
71-43-2	BENZENE	5.1	J	5.1	J	UG/KG	SB-03-11	1/29	5.8 - 2900	5.1	N/A	22000	C	N	BSL
75-15-0	CARBON DISULFIDE	1.4	J	13	J	UG/KG	SB-03-11	6/29	10 - 2900	13	N/A	780000	N	N	BSL
108-90-7	CHLOROBENZENE	11	J	140	J	UG/KG	TP03-03-06	2/29	5.8 - 2900	140	N/A	160000	N	N	BSL
67-66-3	CHLOROFORM	1	J	1	J	UG/KG	TP02-03-04, TP02-03-05	2/29	5.8 - 2900	1	N/A	100000	C	N	BSL
100-41-4	ETHYLBENZENE	4	J	130	J	UG/KG	SB-03-12	3/29	5.8 - 2900	130	N/A	780000	N	N	BSL
75-09-2	METHYLENE CHLORIDE	3300		3300		UG/KG	SB-03-09	1/29	5.8 - 2200	3300	N/A	85000	C	N	BSL
108-88-3	TOLUENE	2	J	120		UG/KG	SB-03-05	9/29	3.3 - 2900	120	N/A	1600000	N	N	BSL
106-46-7	1,4-DICHLOROBENZENE	52	J	120	J	UG/KG	TP03-03-06	2/20	340 - 39000	120	N/A	27000	C	N	BSL
83-32-9	ACENAPHTHENE	110	J	4400	J	UG/KG	SB-03-18	9/26	20 - 39000	4400	N/A	470000	N	N	BSL
208-96-8	ACENAPHTHYLENE	36	J	1200		UG/KG	SB-03-17	9/26	39 - 39000	1200	N/A	160000	N	N	BSL
120-12-7	ANTHRACENE	3.6		21000		UG/KG	SB-03-18	13/26	2 - 39000	21000	N/A	2300000	N	N	BSL
56-55-3	**BENZO(A)ANTHRACENE**	1.2	J	53000		UG/KG	SB-03-18	19/26	340 - 39000	53000	N/A	870	C	Y	ASL
50-32-8	**BENZO(A)PYRENE**	3		44000		UG/KG	SB-03-18	19/26	340 - 39000	44000	N/A	87	C	Y	ASL
205-99-2	**BENZO(B)FLUORANTHENE**	1.7	J	45000		UG/KG	SB-03-18	18/26	340 - 39000	45000	N/A	870	C	Y	ASL
191-24-2	BENZO(G,H,I)PERYLENE	100	J	26000		UG/KG	SB-03-18	15/26	3.9 - 39000	26000	N/A	160000	N	N	BSL
207-08-9	**BENZO(K)FLUORANTHENE**	3		34000		UG/KG	SB-03-18	16/26	2 - 39000	34000	N/A	8700	C	Y	ASL
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	280	J	4000		UG/KG	SB-03-10	2/20	120 - 39000	4000	N/A	46000	C	N	BSL
85-68-7	BUTYL BENZYL PHTHALATE	41	J	41	J	UG/KG	TP03-03-07	1/20	340 - 39000	41	N/A	1600000	N	N	BSL
86-74-8	CARBAZOLE	63	J	1000	J	UG/KG	SB-03-21	5/20	340 - 39000	1000	N/A	32000	C	N	BSL
218-01-9	CHRYSENE	1.1	J	51000		UG/KG	SB-03-18	19/26	340 - 39000	51000	N/A	87000	C	N	BSL
84-74-2	DI-N-BUTYL PHTHALATE	51	J	53	J	UG/KG	SB-03-12	2/20	44 - 39000	53	N/A	780000	N	N	BSL
117-84-0	DI-N-OCTYL PHTHALATE	320	J	320	J	UG/KG	SB-03-10	1/20	340 - 39000	320	N/A	160000	N	N	BSL
53-70-3	**DIBENZO(A,H)ANTHRACENE**	46	J	9400	J	UG/KG	SB-03-18	9/26	3.9 - 39000	9400	N/A	87	C	Y	ASL
132-64-9	DIBENZOFURAN	57	J	300	J	UG/KG	SB-03-12	4/20	340 - 39000	300	N/A	31000	N	N	BSL

TABLE 6-8
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Site 3

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
84-66-2	DIETHYL PHTHALATE	86	J	86	J	UG/KG	TP03-03-06	1/20	340 - 39000	86	N/A	6300000	N	N	BSL
206-44-0	FLUORANTHENE	1.9	J	120000		UG/KG	SB-03-18	20/26	340 - 400	120000	N/A	310000	N	N	BSL
86-73-7	FLUORENE	31	J	4500	J	UG/KG	SB-03-18	10/26	3.9 - 39000	4500	N/A	310000	N	N	BSL
67-72-1	HEXACHLOROETHANE	640		640		UG/KG	TP01-03-03	1/20	340 - 39000	640	N/A	46000	C	N	BSL
193-39-5	INDENO(1,2,3-CD)PYRENE	3.2		29000		UG/KG	SB-03-18	16/26	340 - 39000	29000	N/A	870	C	Y	ASL
91-20-3	NAPHTHALENE	120	J	450	J	UG/KG	SB-03-19-MAX	6/26	20 - 39000	450	N/A	160000	N	N	BSL
85-01-8	PHENANTHRENE	1.8	J	71000		UG/KG	SB-03-18	18/26	340 - 39000	71000	N/A	160000	N	N	BSL
108-95-2	PHENOL	150	J	150	J	UG/KG	SB-03-10	1/20	340 - 39000	150	N/A	4700000	N	N	BSL
129-00-0	PYRENE	3.3		97000		UG/KG	SB-03-18	20/26	340 - 400	97000	N/A	230000	N	N	BSL
309-00-2	ALDRIN	2	J	180	J	UG/KG	SB-03-21	5/12	1.7 - 39	180	N/A	38	C	Y	ASL
53469-21-9	AROCLOR-1242	36	J	84	J	UG/KG	TP03-03-06	2/19	34 - 750	84	N/A	320	C	N	BSL
12672-29-6	AROCLOR-1248	120		120		UG/KG	SB-03-12	1/19	34 - 750	120	N/A	320	C	N	BSL
11097-69-1	AROCLOR-1254	64		5900		UG/KG	SB-03-21	6/19	34 - 750	5900	N/A	320	C	Y	ASL
11096-82-5	AROCLOR-1260	59	J	290	J	UG/KG	TP01-03-03	3/19	34 - 750	290	N/A	320	C	N	BSL
72-20-8	ENDRIN	4.4	J	24	J	UG/KG	SB-03-21	4/13	3.4 - 75	24	N/A	2300	N	N	BSL
58-89-9	GAMMA-BHC (LINDANE)	3.5	J	3.5	J	UG/KG	TP01-03-02	1/12	1.7 - 39	3.5	N/A	490	C	N	BSL
5103-74-2	GAMMA-CHLORDANE	8	J	14	J	UG/KG	SB-03-21	2/13	1.7 - 39	14	N/A	1800	C	N	BSL
1024-57-3	HEPTACHLOR EPOXIDE	6.1	J	6.1	J	UG/KG	TP01-03-03	1/13	1.7 - 39	6.1	N/A	70	C	N	BSL
72-55-9	4,4'-DDE	16	J	42	J	UG/KG	TP01-03-01	4/13	3.4 - 75	42	N/A	1900	C	N	BSL
50-29-3	4,4'-DDT	11	J	31	J	UG/KG	SB-03-07	3/13	3.4 - 75	31	N/A	1900	C	N	BSL
1330-20-7	XYLENES, TOTAL	2.4	J	580	J	UG/KG	SB-03-11	4/29	7.3 - 2900	580	N/A	16000000	N	N	BSL
3268-87-9	OCDD	0.76	J	2.2	J	UG/KG	TP01-03-01	2/4	0.4 - 1.3	2.2	N/A	4.3	C	N	BSL
72-54-8	4,4'-DDD	11	J	150		UG/KG	TP01-03-02	5/12	3.4 - 75	150	N/A	2700	C	N	BSL
91-57-6	2-METHYLNAPHTHALENE	86	J	690		UG/KG	TP01-03-03	4/20	340 - 39000	690	N/A	160000	N	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Solid Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason:
Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason:
Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

TABLE 6-9
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Impoundment Area

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
79-34-5	1,1,2,2-TETRACHLOROETHANE	2	J	2	J	UG/KG	IM605A	1/59	10 - 2800	2	N/A	3200	C	N	BSL
540-59-0	1,2-DICHLOROETHENE (TOTAL)	1	J	11	J	UG/KG	IM201	2/59	10 - 2800	11	N/A	70000	N	N	BSL
78-93-3	2-BUTANONE	6	J	23		UG/KG	IM101	3/59	5 - 2800	23	N/A	4700000	N	N	BSL
108-10-1	4-METHYL-2-PENTANONE	450		450		UG/KG	IM504	1/59	10 - 2800	450	N/A	630000	N	N	BSL
67-64-1	ACETONE	16	J	1100		UG/KG	IM503	8/59	4 - 11000	1100	N/A	780000	N	N	BSL
74-87-3	CHLOROMETHANE	2	J	2	J	UG/KG	IM406	1/59	10 - 1700	2	N/A	49000	C	N	BSL
100-41-4	ETHYLBENZENE	14	J	14	J	UG/KG	IM504	1/59	10 - 2800	14	N/A	780000	N	N	BSL
127-18-4	TETRACHLOROETHENE	10	J	10	J	UG/KG	IM403	1/59	10 - 2800	10	N/A	12000	C	N	BSL
108-88-3	TOLUENE	8	J	8	J	UG/KG	IM101	1/59	10 - 2800	8	N/A	1600000	N	N	BSL
79-01-6	TRICHLOROETHENE	2	J	15	J	UG/KG	IM504	6/59	10 - 2800	15	N/A	58000	C	N	BSL
91-57-6	2-METHYLNAPHTHALENE	44	J	44	J	UG/KG	IM505	1/30	320 - 4200	44	N/A	160000	N	N	BSL
106-44-5	4-METHYLPHENOL	160	J	160	J	UG/KG	IM307	1/30	320 - 4200	160	N/A	39000	N	N	BSL
208-96-8	ACENAPHTHYLENE	560	J	560	J	UG/KG	IM302	1/30	320 - 4200	560	N/A	160000	N	N	BSL
120-12-7	ANTHRACENE	510	J	510	J	UG/KG	IM302	1/30	320 - 4200	510	N/A	2300000	N	N	BSL
56-55-3	**BENZO(A)ANTHRACENE**	49	J	2700	J	UG/KG	IM107	8/30	320 - 920	2700	N/A	870	C	Y	ASL
50-32-8	**BENZO(A)PYRENE**	45	J	3000	J	UG/KG	IM107	8/30	320 - 920	3000	N/A	87	C	Y	ASL
205-99-2	**BENZO(B)FLUORANTHENE**	46	J	2800	J	UG/KG	IM107	9/30	320 - 920	2800	N/A	870	C	Y	ASL
191-24-2	BENZO(G,H,I)PERYLENE	46	J	1700	J	UG/KG	IM107	7/30	320 - 450	1700	N/A	160000	N	N	BSL
207-08-9	BENZO(K)FLUORANTHENE	51	J	1100	J	UG/KG	IM107	6/30	320 - 920	1100	N/A	8700	C	N	BSL
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	45	J	320	J	UG/KG	IM711	16/30	100 - 4200	320	N/A	46000	C	N	BSL
218-01-9	CHRYSENE	60	J	3300	J	UG/KG	IM107	8/30	320 - 920	3300	N/A	87000	C	N	BSL
53-70-3	DIBENZO(A,H)ANTHRACENE	34	J	34	J	UG/KG	IM410	1/30	320 - 4200	34	N/A	87	C	N	BSL
84-74-2	DI-N-BUTYL PHTHALATE	55	J	110	J	UG/KG	IM201	4/30	320 - 4200	110	N/A	780000	N	N	BSL
206-44-0	FLUORANTHENE	48	J	3700	J	UG/KG	IM107	11/30	320 - 920	3700	N/A	310000	N	N	BSL
86-73-7	FLUORENE	240	J	240	J	UG/KG	IM302	1/30	320 - 4200	240	N/A	310000	N	N	BSL
193-39-5	**INDENO(1,2,3-CD)PYRENE**	45	J	1300	J	UG/KG	IM107	7/30	320 - 920	1300	N/A	870	C	Y	ASL
87-86-5	PENTACHLOROPHENOL	120	J	120	J	UG/KG	IM711	1/30	820 - 10000	120	N/A	5300	C	N	BSL
85-01-8	PHENANTHRENE	56	J	1900	J	UG/KG	IM302	6/30	320 - 920	1900	N/A	160000	N	N	BSL
129-00-0	PYRENE	42	J	7000		UG/KG	IM107	11/30	320 - 920	7000	N/A	230000	N	N	BSL
72-54-8	4,4'-DDD	0.11	J	150		UG/KG	IM501	11/30	3.8 - 4.5	150	N/A	2700	C	N	BSL
72-55-9	4,4'-DDE	0.29	J	3.7	J	UG/KG	IM501	7/30	3.8 - 42	3.7	N/A	1900	C	N	BSL
50-29-3	4,4'-DDT	0.51	J	78		UG/KG	IM711	9/30	3.6 - 4.5	78	N/A	1900	C	N	BSL
309-00-2	ALDRIN	2.3	J	2.3	J	UG/KG	IM301	1/30	1.8 - 22	2.3	N/A	38	C	N	BSL
5103-71-9	ALPHA-CHLORDANE	0.25	J	0.25	J	UG/KG	IM309	1/30	1.8 - 22	0.25	N/A	1800	C	N	BSL
53469-21-9	AROCLOR-1242	31	J	31	J	UG/KG	IM309	1/30	36 - 420	31	N/A	320	C	N	BSL
11097-69-1	AROCLOR-1254	16	J	44		UG/KG	IM410	6/30	38 - 420	44	N/A	320	C	N	BSL
11096-82-5	**AROCLOR-1260**	21	J	930		UG/KG	IM711	5/30	36 - 420	930	N/A	320	C	Y	ASL
319-86-8	DELTA-BHC	0.067	J	9.9	J	UG/KG	IM711	2/30	0.34 - 22	9.9	N/A	100	C	N	BSL
60-57-1	DIELDRIN	0.046	J	21		UG/KG	IM711	6/30	3.6 - 4.5	21	N/A	40	C	N	BSL
959-98-8	ENDOSULFAN I	0.071	J	0.8	J	UG/KG	IM307	2/30	1.8 - 22	0.8	N/A	47000	N	N	BSL
33213-65-9	ENDOSULFAN II	0.11	J	19	J	UG/KG	IM711	4/30	3.6 - 42	19	N/A	47000	N	N	BSL
72-20-8	ENDRIN	0.094	J	13	J	UG/KG	IM302	4/30	3.6 - 18	13	N/A	2300	N	N	BSL
7421-93-4	ENDRIN ALDEHYDE	0.63	J	0.63	J	UG/KG	IM307	1/30	3.6 - 42	0.63	N/A	2300	N	N	BSL
53494-70-5	ENDRIN KETONE	0.12	J	13	J	UG/KG	IM107	3/30	3.6 - 18	13	N/A	2300	N	N	BSL
58-89-9	GAMMA-BHC (LINDANE)	0.14	J	0.19	J	UG/KG	IM410	2/30	0.3 - 22	0.19	N/A	490	C	N	BSL
5103-74-2	GAMMA-CHLORDANE	0.067	J	13	J	UG/KG	IM711	4/30	1.8 - 2.3	13	N/A	1800	C	N	BSL
76-44-8	HEPTACHLOR	0.061	J	1.2	J	UG/KG	IM307	2/30	1.8 - 22	1.2	N/A	140	C	N	BSL
1024-57-3	HEPTACHLOR EPOXIDE	0.059	J	0.059	J	UG/KG	IM412	1/30	0.29 - 22	0.059	N/A	70	C	N	BSL
72-43-5	METHOXYCHLOR	0.81	J	0.81	J	UG/KG	IM410	1/30	0.37 - 220	0.81	N/A	39000	N	N	BSL

TABLE 6-9

OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN, IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Impoundment Area

CAS Number	Chemical	Minimum (1) Concentration	Minimum Qualifier	Maximum (1) Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Site Greater Than Background (2)	Screening (3) Toxicity Value		COPC Flag	Rationale for (4) Contaminant Deletion or Selection
7429-90-5	ALUMINUM	4500		20100		MG/KG	IM409	65/65	N/A	20100	N	7800	N	N	BKG
7440-36-0	**ANTIMONY**	0.56	J	144	J	MG/KG	IM711	10/39	0.4 - 10.1	144	Y	3.1	N	Y	ASL
7440-38-2	ARSENIC	0.42		6.4		MG/KG	IM711	40/65	0.37 - 2.1	6.4	N	0.43	C	N	BKG
7440-39-3	BARIUM	36	J	316		MG/KG	IM711	65/65	N/A	316	N	550	N	N	BSL
7440-41-7	BERYLLIUM	0.37	J	6.7		MG/KG	IM503	56/65	0.38 - 1.1	6.7	N	16	N	N	BSL
7440-43-9	**CADMIUM**	0.59	J	91.1		MG/KG	IM101A	10/65	0.04 - 2.1	91.1	Y	3.9	N	Y	ASL
7440-70-2	CALCIUM	552		132000		MG/KG	IM711	65/65	N/A	132000	Y		N	N	NUT
7440-47-3	**CHROMIUM**	2.5	J	4730		MG/KG	IM711	65/65	N/A	4730	Y	23	N	Y	ASL
7440-48-4	COBALT	2.2		61.4		MG/KG	IM711	64/65	8.9	61.4	Y	470	N	N	BSL
7440-50-8	**COPPER**	2.2	J	707	J	MG/KG	IM711	49/65	1.1 - 9.5	707	Y	310	N	Y	ASL
57-12-5	CYANIDE	0.66		79.6		MG/KG	IM711	9/37	0.55 - 3.1	79.6	Y	160	N	N	BSL
18540299	HEXAVALENT CHROMIUM	0.9	J	22.5	J	MG/KG	IM406	14/39	0.01 - 2.4	22.5	Y	23	N	N	BSL
7439-89-6	IRON	3350		91700		MG/KG	IM101	65/65	N/A	91700	N	2300	N	N	BKG
7439-92-1	LEAD	0.59		89.8		MG/KG	IM711	58/65	2.6 - 5.9	89.8	N	400	C	N	BSL
7439-95-4	MAGNESIUM	542		42800		MG/KG	IM301	65/65	N/A	42800	Y		N	N	NUT
7439-96-5	**MANGANESE**	90.3		6090		MG/KG	IM503	65/65	N/A	6090	Y	160	N	Y	ASL
7439-97-6	**MERCURY**	0.06		2.6		MG/KG	IM307	13/65	0.04 - 0.12	2.6	Y	2.3	N	Y	ASL
7440-02-0	NICKEL	3.3		62.7		MG/KG	IM101	65/65	N/A	62.7	Y	160	N	N	BSL
7440-09-7	POTASSIUM	189		5680		MG/KG	IM409	62/65	667 - 864	5680	Y		N	N	NUT
7440-22-4	**SILVER**	0.59	J	373	J	MG/KG	IM711	14/65	0.16 - 1.1	373	Y	39	N	Y	ASL
7440-23-5	SODIUM	68.8		612		MG/KG	IM409	20/65	44.9 - 527	612	N		N	N	NUT
7440-28-0	THALLIUM	1.1	J	1.1	J	MG/KG	IM301	1/65	0.69 - 1.5	1.1	N	0.55	N	N	BKG
7440-62-2	VANADIUM	4.8		33.7		MG/KG	IM101A	65/65	N/A	33.7	N	55	N	N	BSL
7440-66-6	ZINC	9.9	J	327	J	MG/KG	IM711	49/65	10.9 - 46.4	327	Y	2300	N	N	BSL

(1) Mimimum/maximum detected concentration
(2) Refer to supporting information for background discussion.
Y - Site (>) Background; N - Site (not >) Background; NA - Not Applicable (inorganics - insufficient site or back info; organics).
(3) EPA Region III Risk-Based Concentration Screening Values (Residential Land Use) (EPA, 10/27/99). Office of Soild Waste and Emergency Response (OSWER) [for lead only] (EPA, 1994).
(4) Rationale Codes Selection Reason:
Infrequent Detection but Associated Historically (HIST)
Frequent Detection (FD)
Toxicity Information Available (TX)
Above Screening Levels (ASL)
Deletion Reason:
Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information, discussed in uncertainty section of HHRA (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
N/A = Not Applicable
COPC = Chemical of Potential Concern
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

TABLE 6-10
RESIDENTIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SUBSURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 1	INORGANICS					
	ANTIMONY	15.20	3.13E+01	N/A	0.49	N/A
	CADMIUM	61.40	7.80E+01	N/A	0.79	N/A
	CHROMIUM VI	4600.00	2.35E+02	N/A	19.60	N/A
	MANGANESE	2630.00	1.56E+03	N/A	1.68	N/A
	MERCURY	6.80	7.82E+00	N/A	0.87	N/A
	SILVER	360.00	3.91E+02	N/A	0.92	N/A
	THALLIUM	1.70	5.48E+00	N/A	0.31	N/A
				TOTAL:	**24.66**	**0.00**
Site 2	PAH(s)					
	BENZ[A]ANTHRACENE	5.20	N/A	8.75E-01	N/A	5.94E-06
	BENZO[A]PYRENE	3.80	N/A	8.75E-02	N/A	4.34E-05
	BENZO[B]FLUORANTHENE	4.90	N/A	8.75E-01	N/A	5.60E-06
	DIBENZ[A,H]ANTHRACENE	0.45	N/A	8.75E-02	N/A	5.14E-06
	INDENO[1,2,3-C,D]PYRENE	2.50	N/A	8.75E-01	N/A	2.86E-06
	PESTICIDES					
	AROCLOR-1254	1.15	3.19E-01	3.19E-01	3.60	3.60E-06
	AROCLOR-1260	1.60	3.19E-01	3.19E-01	5.01	5.01E-06
	INORGANICS					
	ALUMINUM	133000.00	7.82E+04	N/A	1.70	N/A
	ANTIMONY	90.50	3.13E+01	N/A	2.89	N/A
	ARSENIC	19.60	4.26E-01	4.26E-01	46.03	4.60E-05
	BARIUM	620.00	5.48E+03	N/A	0.11	N/A
	CADMIUM	293.00	7.82E+01	N/A	3.75	N/A
	CHROMIUM VI	3840.00	2.35E+02	N/A	16.37	N/A
	COPPER	7050.00	3.13E+03	N/A	2.25	N/A

TABLE 6-10
RESIDENTIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SUBSURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 2	MANGANESE	1240.00	1.56E+03	N/A	0.79	N/A
	NICKEL	143.00	1.56E+03	N/A	0.09	N/A
	SILVER	168.00	3.91E+02	N/A	0.43	N/A
	THALLIUM	0.69	5.48E+00	N/A	0.13	N/A
	VANADIUM	586.00	5.48E+02	N/A	1.07	N/A
	ZINC	5640.00	2.35E+04	N/A	0.24	N/A
				TOTAL:	**84.45**	**1.18E-04**
Site 3	PAH(s)					
	BENZ[A]ANTHRACENE	53.00	N/A	8.75E-01	N/A	6.06E-05
	BENZO[A]PYRENE	44.00	N/A	8.75E-02	N/A	5.03E-04
	BENZO[B]FLUORANTHENE	45.00	N/A	8.75E-01	N/A	5.14E-05
	BENZO[K]FLUORANTHENE	34.00	N/A	8.75E+00	N/A	3.89E-06
	DIBENZ[A,H]ANTHRACENE	9.40	N/A	8.75E-02	N/A	1.07E-04
	INDENO[1,2,3-C,D]PYRENE	29.00	N/A	8.75E-01	N/A	3.31E-05
	PESTICIDES					
	ALDRIN	0.18	3.76E-02	3.76E-02	4.79	4.79E-06
	AROCLOR-1254	5.90	3.19E-01	3.19E-01	18.47	1.85E-05
	INORGANICS					
	ANTIMONY	16.60	3.13E+01	N/A	0.53	N/A
	ARSENIC	17.60	4.26E-01	4.26E-01	41.33	4.13E-05
	BARIUM	1530.00	5.48E+03	N/A	0.28	N/A
	CADMIUM	67.10	7.82E+01	N/A	0.86	N/A
	CHROMIUM VI	83.40	2.35E+02	N/A	0.36	N/A
	COPPER	3760.00	3.13E+03	N/A	1.20	N/A
	LEAD	30.40	N/A	N/A	N/A	N/A

TABLE 6-10
RESIDENTIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SUBSURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 3	MANGANESE	2330.00	1.56E+03	N/A	1.49	N/A
	MERCURY	9.70	7.82E+00	N/A	1.24	N/A
	NICKEL	368.00	1.56E+03	N/A	0.24	N/A
	SILVER	144.00	3.91E+02	N/A	0.37	N/A
	THALLIUM	1.40	5.48E+00	N/A	0.26	N/A
	VANADIUM	284.00	5.48E+02	N/A	0.52	N/A
	ZINC	9100.00	2.35E+04	N/A	0.39	N/A
				TOTAL:	**72.32**	**8.24E-04**
Impoundment Area	PAH(s)					
	BENZ[A]ANTHRACENE	2.70	N/A	8.75E-01	N/A	3.09E-06
	BENZO[A]PYRENE	3.00	N/A	8.75E-02	N/A	3.43E-05
	BENZO[B]FLUORANTHENE	2.80	N/A	8.75E-01	N/A	3.20E-06
	INDENO[1,2,3-C,D]PYRENE	1.30	N/A	8.75E-01	N/A	1.49E-06
	PESTICIDES					
	AROCLOR-1260	0.93	3.19E-01	3.19E-01	2.91	2.91E-06
	INORGANICS					
	ANTIMONY	144.00	3.13E+01	N/A	4.60	N/A
	CADMIUM	91.10	7.82E+01	N/A	1.16	N/A
	CHROMIUM VI	4730.00	2.35E+02	N/A	20.16	N/A
	COPPER	707.00	3.13E+03	N/A	0.23	N/A
	MANGANESE	6090.00	1.56E+03	N/A	3.89	N/A
	MERCURY	2.60	7.82E+00	N/A	0.33	N/A
	SILVER	373.00	3.91E+02	N/A	0.95	N/A
				TOTAL:	**34.24**	**4.50E-05**

TABLE 6-11
INDUSTRIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SUBSURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Site 1	INORGANICS					
	CHROMIUM VI	4600.00	6.13E+03	N/A	0.75	N/A
				TOTAL:	**0.75**	**0.00**
Site 2	PAH(s)					
	BENZ[A]ANTHRACENE	5.20	N/A	7.84E+00	N/A	6.63E-07
	INORGANICS					
	ANTIMONY	90.50	8.18E+02	N/A	0.11	N/A
	ARSENIC	19.60	3.82E+00	3.82E+00	5.14	5.14E-06
	CADMIUM	293.00	2.04E+03	N/A	0.14	N/A
	CHROMIUM VI	3840.00	6.13E+03	N/A	0.63	N/A
	THALLIUM	0.69	1.43E+02	N/A	0.00	N/A
				TOTAL:	**6.02**	**5.80E-06**
Site 3	PAH(s)					
	BENZ[A]ANTHRACENE	53.00	N/A	7.84E+00	N/A	6.76E-06
	BENZO[A]PYRENE	44.00	N/A	7.84E-01	N/A	5.61E-05
	BENZO[B]FLUORANTHENE	45.00	N/A	7.84E+00	N/A	5.74E-06
	DIBENZ[A,H]ANTHRACENE	9.40	N/A	7.84E-01	N/A	1.20E-05
	INDENO[1,2,3-C,D]PYRENE	29.00	N/A	7.84E+00	N/A	3.70E-06
	PESTICIDES					
	AROCLOR-1254	5.90	2.86E+00	2.86E+00	2.06	2.06E-06
	INORGANICS					
	ARSENIC	17.60	3.82E+00	3.82E+00	4.61	4.61E-06
				TOTAL:	**6.67**	**9.10E-05**

TABLE 6-11
INDUSTRIAL RISK RATIO SUMMARY TABLE FOR COPCs IN AREA A SUBSURFACE SOILS (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

	COPC	Maximum Detected Concentration (mg/kg)	RBC for Noncarcinogens	RBC for Carcinogens	Risk Ratio: Noncarcinogenic Endpoint	Risk Ratio: Carcinogenic Endpoint
Impoundment Area	PAH(s)					
	BENZO[A]PYRENE	3.00	N/A	7.84E-01	N/A	3.83E-06
	INORGANICS					
	ANTIMONY	144.00	8.18E+02	N/A	0.18	N/A
	CHROMIUM VI	4730.00	6.13E+03	N/A	0.77	N/A
	MANGANESE	6090.00	4.09E+04	N/A	0.15	N/A
				TOTAL:	**1.10**	**3.83E-06**

- Barium
- Copper
- Iron
- Lead
- Manganese
- Nickel
- Zinc
- Aluminum
- Chromium
- Thallium

6.2.3.4 Sediment COPC Selection

Potential COPCs for sediment water were based on various aspects of their occurrence and distribution, mobility, persistence, and toxicity. These chemicals are selected to represent site contamination and provide the framework for the quantitative risk assessment. Comparisons of site-related inorganic concentrations of chemicals detected in sediment were made to appropriate and whether these chemicals were considered to be background concentrations and essential nutrients or minerals. All organics detected in sediment were selected as COCs.

A variety of metals, PAHs, VOCs, PCBs, and phthalates were considered to be notable in downstream Area A sediment. The chemicals that were positively detected in sediment in Area A are presented in Tables 4-25 and 4-26 The large number of COCs selected may reflect the chemicals being discharged through base outfall no. 1. The following chemicals were selected as COCs in site-related sediment:

- 1,1,1-TCA
- 1,1-DCE
- 1,2-DCE (Total)
- 2-Butanone
- 2-Methylnaphthalene
- 4,4'-DDD
- 4,4'-DDT
- 4,4'-DDE
- 4-Methylphenol
- Acenaphthene
- Acetone
- Aldrin
- Alpha-Chlordane
- Anthracene
- Aroclor 1016
- Aroclor 1248
- Aroclor 1254
- Aroclor 1260
- Benz(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Carbazole
- Benzo(k)fluoranthene
- Benzo(g,h,i)perylene
- Chloroform
- Benzo(b)fluoranthene
- Bis(2-thylhexyl)phthalate
- Chloromethane
- Chrysene
- Butylbenzylphthalate
- Delta-BHC
- Di-n-butylphthalate
- Carbon Tetrachloride
- Dibenzofuran
- Di-n-octylphthalate
- Dibenz(a,h)anthracene
- Dieldrin
- Endosulfan II
- Endosulfan Sulfate
- Endrin
- Endrin Aldehyde
- Endrin Ketone
- Ethylbenzene
- Fluoranthene
- Fluorene
- Gamma-Chlordane
- Naphthalene
- Indeno(1,2,3-cd)pyrene
- Pyrene
- PCE
- Toluene
- TCE
- Total Xylenes
- Aluminum
- Arsenic
- Barium
- Beryllium

- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Silver
- Vanadium
- Zinc

6.2.4 Distributional Analysis of the Data

This section presents the approaches taken for distributional analysis of the Area A analytical data. Distributional analysis of the sampling data is important in determining the exposure point concentration (EPC) used to quantitatively estimate risks at the site. Statistical analyses discussed in this section adhere to the guidance referenced in several EPA and related publications (EPA, 1989a, 1989b, 1992a, 1992b, and 1996a). Before EPCs were estimated for each COPC, the underlying statistical distribution of data was determined. The Shapiro-Wilk (W) test or the Shapiro-Francia Test (EPA, 1992a) were performed to determine if the data set of chemical concentrations matched the shape of a normal or lognormal distribution. [The latter test is required if there are greater than 50 samples (EPA, 1992a, 1996a).] Normally distributed data exhibit a characteristic "bell-shape" curve that is symmetrical, whereas lognormal data have a skewed shape (a longer tail at the high-concentration tail).

For each COPC, the W test was performed once using the original data and once after data were converted to their logarithms. A 5% level of significance was used to determine if the data deviated from either hypothesized distribution. If the W test indicated a normal distribution, then the estimation of the reasonable maximum exposure point concentration (using the upper 95th percentile confidence limit on the mean, as discussed in the next section) was based upon a normal distribution and standard deviation. If taking the logarithms of the data provided a better match than a normal distribution, a lognormal transformation of data was performed before the upper 95th percentile confidence limit on the mean concentrations was computed. If neither distribution matched the data set of interest, the default assumption of an underlying lognormal distribution was followed (EPA, 1989a).

The distributional analysis results for residential COPCs in surface soil and subsurface soil are shown in the following tables:

- Site 1 subsurface soil - Table 6-12
- Site 2 surface soil - Table 6-13
- Site 2 subsurface soil - Table 6-14
- Site 3 surface soil - Table 6-15
- Site 3 subsurface soil - Table 6-16
- Impoundment area subsurface soil - Table 6-17

TABLE 6-12
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 1 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Substance	Number of Sample Results	Degrees of Freedom	Statistical Distribution of Site Data	Results of Shapiro-Wilk or Shapiro-Francia Distribution Tests			Table Value for $H_{0.95}$ (Lognorm.) or $T_{0.95}$ (Norm.)	Standard Deviation or Log Standard Deviation	Arithmetic Mean of All Site Results	Upper 95% Confidence Limit (UCL) on Mean	Maximum Positive Site Concentration
				W-norm	W-lognorm	W-Table					
ALUMINUM	17	16	nonparametric (assumed lognorm.)	0.7383	0.7874	0.892	1.8958	0.3370	15,852	18,710	33,500
ANTIMONY	30	29	nonparametric (assumed lognorm.)	0.5595	0.8553	0.927	3.0304	1.4493	1.91	3.60	15.2
ARSENIC	17	16	lognormal	0.6388	0.9548	0.892	2.4686	0.8510	5.12	8.32	25.5
BARIUM	17	16	lognormal	0.8592	0.9529	0.892	2.1365	0.5884	93.2	130	210
BERYLLIUM	17	16	lognormal	0.9574	0.9624	0.892	2.174	0.6210	1.40	2.03	3.10
CADMIUM	40	39	nonparametric (assumed lognorm.)	0.4094	0.8808	0.94	3.9282	2.1364	6.01	15.5	61.4
CALCIUM	17	16	nonparametric (assumed lognorm.)	0.2992	0.7481	0.892	2.9084	1.1406	4,220	5,468	53,400
CHROMIUM	39	38	nonparametric (assumed lognorm.)	0.3437	0.7649	0.939	3.0176	1.5139	250	233	4,600
COBALT	17	16	lognormal	0.6548	0.9015	0.892	2.2538	0.6883	17.2	25.8	66.1
COPPER	17	16	lognormal	0.7421	0.9604	0.892	3.526	1.5080	65.7	310	299
CYANIDE	5	4	lognormal	0.7634	0.8787	0.762	3.5362	0.6665	0.69	2.29	1.60
IRON	17	16	nonparametric (assumed lognorm.)	0.4432	0.8627	0.892	2.3302	0.7481	38,462	53,412	251,000
LEAD	24	23	lognormal	0.5168	0.9515	0.916	2.4219	0.9210	19.7	31.3	135
MAGNESIUM	17	16	nonparametric (assumed lognorm.)	0.8721	0.8524	0.892	2.6593	0.9833	3,084	6,769	5,890
MANGANESE	17	16	lognormal	0.8141	0.9494	0.892	2.2449	0.6808	848	1,264	2,630
MERCURY	17	16	nonparametric (assumed lognorm.)	0.2785	0.6396	0.892	3.0635	1.2378	0.47	0.46	6.80
NICKEL	17	16	lognormal	0.6197	0.9653	0.892	2.3982	0.8004	18.0	28.6	87.9
POTASSIUM	17	16	nonparametric (assumed lognorm.)	0.7981	0.8723	0.892	3.4026	1.4364	1,888	8,820	4,600
SELENIUM	17	16	lognormal	0.7098	0.9269	0.892	2.5562	0.9133	0.72	1.29	3.30
SILVER	17	16	nonparametric (assumed lognorm.)	0.2674	0.5915	0.892	3.7025	1.6064	22.0	17	360
SODIUM	17	16	lognormal	0.561	0.9368	0.892	2.4673	0.8501	134	226	707
THALLIUM	24	23	lognormal	0.8123	0.9678	0.916	2.0125	0.5455	0.55	0.69	1.70
VANADIUM	17	16	lognormal	0.839	0.9239	0.892	2.0208	0.4780	30.1	38.4	66.6
ZINC	17	16	nonparametric (assumed lognorm.)	0.4425	0.8803	0.892	2.4666	0.8495	67.1	104	451
2-BUTANONE	6	5	nonparametric (assumed lognorm.)	0.7501	0.7304	0.788	1.984	0.1175	6.05	6.72	4.8
4,4'-DDD	2	1	unknown (assumed lognorm.)	---	---	---	21.0493	2.3260	5.52	2.91E+23	1.6
4,4'-DDE	2	1	unknown (assumed lognorm.)	---	---	---	6.5463	0.7257	4.82	1,081	2.9
4-METHYL-2-PENTANONE	6	5	nonparametric (assumed lognorm.)	0.5946	0.5516	0.788	2.872	0.5606	175	12.0	40.0
AROCLOR-1254	8	7	nonparametric (assumed lognorm.)	0.4998	0.5385	0.818	2.0353	0.2665	22.1	27.1	41.0
BIS(2-ETHYLHEXYL)PHTHALATE	8	7	nonparametric (assumed lognorm.)	0.5347	0.477	0.818	2.4955	0.5596	3.43	316	4.8
ENDRIN	2	1	unknown (assumed lognorm.)	---	---	---	6.4191	0.6016	28.5	97.9	55.00
TOLUENE	6	5	nonparametric (assumed lognorm.)	0.7742	0.7242	0.788	3.451	0.7516	8.15	17.1	12.0

Notes:
Bold Text Indicates selected COPC for this media.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.
Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.
A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.
A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.
H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.
Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).
The representative concentration is select ed as the lowr of the 95% UCL on the mean and the maximum positive site concentration.

TABLE 6-13
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Substance	Number of Sample Results	Number of Sample Results Detected	Statistical Distribution Model Used	Results of Shapiro-Francia Distribution Test: W-norm	W-lognorm	W-critical	Test Value for Log-Normal Model (Normality)	Standard Deviation of Log Standard Deviations	Arithmetic Mean of All Sample Results	95% Upper Confidence Limit (UCL) on Mean	Maximum Positive Sample Concentration
ALUMINUM	20	19	non-parametric (assume lognormal)	0.9028	0.4275	0.905	2.644	2.812	12,738	33,366	19,800
ANTIMONY	46	45	non-parametric (assume lognormal)	0.7127	0.8887	0.945	2.6927	3.881	2.16	3.81	10.8
ARSENIC	20	19	non-parametric (assume lognormal)	0.891	0.8628	0.905	2.0273	1.6912	5.40	7.10	13.1
BARIUM	20	19	non-parametric (assume lognormal)	0.7596	0.8418	0.905	2.4758	2.4918	119	224	452
BERYLLIUM	20	19	normal	0.9183	0.5535	0.905	1.729	0.31	0.94	1.06	1.4
CADMIUM	48	47	lognormal	0.6253	0.9583	0.947	3.2503	4.8797	2.55	7.66	20.3
CALCIUM	20	19	lognormal	0.3996	0.9132	0.905	3.162	3.9549	19,443	42,064	215,000
CHROMIUM	24	23	non-parametric (assume lognormal)	0.8236	0.8191	0.916	2.4553	2.579	46.6	87.6	133
COBALT	20	19	non-parametric (assume lognormal)	0.768	0.4392	0.905	2.1327	1.8757	11.0	16.6	14.5
COPPER	44	43	non-parametric (assume lognormal)	0.4814	0.8831	0.944	2.8031	3.9892	114	161	1410
IRON	20	19	normal	0.9156	0.6548	0.905	1.729	8,058.04	22,818	25,933	38,000
LEAD	48	47	non-parametric (assume lognormal)	0.5821	0.8634	0.947	2.6355	3.5824	108	152	994
MAGNESIUM	20	19	non-parametric (assume lognormal)	0.3534	0.8229	0.905	2.5962	2.7223	12,346	16,429	135,000
MANGANESE	20	19	lognormal	0.7887	0.943	0.905	2.0043	1.6523	711	903	2,080
MERCURY	20	19	lognormal	0.7628	0.9476	0.905	2.8353	1.7754	0.25	0.57	1.1
NICKEL	20	19	lognormal	0.83	0.9433	0.905	2.109	1.7217	15.3	20.7	47
POTASSIUM	20	19	normal	0.9314	0.6577	0.905	1.729	712.50	1,403	1,679	2,590
SELENIUM	18	17	non-parametric (assume lognormal)	0.6441	0.8257	0.897	2.1123	1.3408	0.47	0.61	1.6
SILVER	43	42	non-parametric (assume lognormal)	0.4365	0.9424	0.943	3.9303	4.9582	3.83	23.3	58.4
SODIUM	20	19	lognormal	0.5543	0.9374	0.905	2.6655	2.2146	273	500	1,870
THALLIUM	24	23	non-parametric (assume lognormal)	0.7402	0.8356	0.916	2.1395	1.2284	0.51	0.68	1.4
VANADIUM	20	19	non-parametric (assume lognormal)	0.6469	0.8307	0.905	1.9133	1.4874	39.1	46.0	119
ZINC	44	43	non-parametric (assume lognormal)	0.4095	0.9	0.944	2.6616	3.565	319	428	4,800
2-METHYLNAPHTHALENE	20	19	non-parametric (assume lognormal)	0.2543	0.5364	0.905	2.8376	75.9492	1,264	1,033	21,000
ACENAPHTHENE	20	19	non-parametric (assume lognormal)	0.261	0.5958	0.905	2.7977	1.8578	1,033	923	180
ACENAPHTHYLENE	20	19	non-parametric (assume lognormal)	0.264	0.6742	0.905	2.8846	2.4292	1,027	982	440
ANTHRACENE	20	19	non-parametric (assume lognormal)	0.2675	0.7591	0.905	2.9078	2.4096	1,037	1,058	640
BENZO(A)ANTHRACENE	23	22	non-parametric (assume lognormal)	0.3784	0.8352	0.914	2.7992	2.4971	1,413	2,198	3,300
BENZO(A)PYRENE	24	23	lognormal	0.3823	0.9364	0.916	2.8653	2.7822	1,433	2,590	3,400
BENZO(B)FLUORANTHENE	20	19	lognormal	0.5171	0.9143	0.905	3.0563	2.5759	2,015	4,841	5,300
BENZO(G,H,I)PERYLENE	38	37	non-parametric (assume lognormal)	0.3913	0.9113	0.938	2.6655	3.3509	1,129	1,522	4,400
BENZO(K)FLUORANTHENE	20	19	non-parametric (assume lognormal)	0.3294	0.8287	0.905	2.7628	2.138	1,314	1,756	1,800
BIS(2-ETHYLHEXYL)PHTHALATE	20	19	non-parametric (assume lognormal)	0.3114	0.8578	0.905	3.4277	1.5153	1,115	2,093	1,800
CARBAZOLE	20	19	non-parametric (assume lognormal)	0.2539	0.6074	0.905	2.8049	2.0645	1,000	825	560
CHRYSENE	20	19	non-parametric (assume lognormal)	0.4122	0.8844	0.905	2.9031	2.3317	1,633	3,009	3,300
DIBENZO(A,H)ANTHRACENE	20	19	non-parametric (assume lognormal)	0.2523	0.6139	0.905	2.8177	2.259	1,033	819	61
DIBENZOFURAN	20	19	non-parametric (assume lognormal)	0.2641	0.6826	0.905	2.9058	1.3235	994	979	470
DI-N-BUTYL PHTHALATE	20	19	non-parametric (assume lognormal)	0.2615	0.6145	0.905	2.8337	1.2805	1,022	958	73
FLUORANTHENE	20	19	lognormal	0.5441	0.9384	0.905	3.0337	2.3514	2,141	5,211	6,200
FLUORENE	20	19	non-parametric (assume lognormal)	0.2502	0.5574	0.905	2.7527	1.7151	997	782	250
INDENO(1,2,3-CD)PYRENE	41	40	lognormal	0.4204	0.952	0.941	2.7745	3.7836	1,151	1,717	5,000
NAPHTHALENE	20	19	non-parametric (assume lognormal)	0.2591	0.538	0.905	2.752	1	1,039	907	52
PHENANTHRENE	20	19	non-parametric (assume lognormal)	0.3956	0.8758	0.905	2.9879	2.7552	1,511	2,742	3,700
PYRENE	20	19	lognormal	0.4915	0.9252	0.905	2.9927	2.3973	1,925	4,297	4,600
TOLUENE	12	11	non-parametric (assume lognormal)	0.5645	0.6816	0.859	2.0709	1	6.08	8.04	2
4,4'-DDD	12	11	non-parametric (assume lognormal)	0.346	0.4032	0.859	2.3796	1	3.28	4.57	19
4,4'-DDE	12	11	non-parametric (assume lognormal)	0.5203	0.5623	0.859	2.3072	1	3.08	4.54	7.9
4,4'-DDT	12	11	non-parametric (assume lognormal)	0.6451	0.796	0.859	2.6844	2.1553	5.32	10.3	23
ALPHA-CHLORDANE	12	11	non-parametric (assume lognormal)	0.3627	0.5972	0.859	4.0826	12.3001	15.3	50.4	160
AROCLOR-1254	20	19	non-parametric (assume lognormal)	0.3546	0.8622	0.905	3.3559	4.3436	284	596	3,700
AROCLOR-1260	20	19	non-parametric (assume lognormal)	0.4531	0.5446	0.905	2.0319	1	27.7	33.5	110
DIELDRIN	12	11	non-parametric (assume lognormal)	0.448	0.5419	0.859	2.7878	1	5.08	9.05	32

TABLE 6-13
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ENDRIN	12	11	non-parametric (assume lognormal)	0.3598	0.7123	0.859	4.0714	6.5915	35.4	123	370
GAMMA-BHC (LINDANE)	12	11	non-parametric (assume lognormal)	0.6767	0.8492	0.859	2.577	1.3962	2.65	4.84	5
GAMMA-CHLORDANE	12	11	non-parametric (assume lognormal)	0.4809	0.5117	0.859	2.8236	1	2.58	4.98	11

Notes:
Bold Text Indicates selected COPC for this media.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.
Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.
A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.
A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.
H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.
Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).
The representative concentration is selected as the lower of the 95% UCL on the mean and the maximum positive site concentration.

TABLE 6-14
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Substance	Number of Sample Results	Degrees of Freedom	Statistical Distribution of Site Data	Results of Shapiro-Wilk or Shapiro-Francia Distribution Tests			Table Value for $H_{0.95}$ (Lognorm.) or $T_{0.95}$ (Norm.)	Standard Deviation or Log Standard Deviation	Arithmetic Mean of All Site Results	Upper 95% Confidence Limit (UCL) on Mean	Maximum Positive Site Concentration
				W-norm	W-lognorm	W-Table					
ALUMINUM	58	57	nonparametric (assume lognormal)	0.2867	0.8017	0.981	1.8581	0.4817	15,500	16,637	133,000
ANTIMONY	67	66	nonparametric (assume lognormal)	0.393	0.8895	0.983	2.6951	1.3860	7.27	11.47	90.5
ARSENIC	58	57	nonparametric (assume lognormal)	0.7886	0.9465	0.981	2.0583	0.7497	4.94	6.26	19.6
BARIUM	58	57	nonparametric (assume lognormal)	0.5985	0.9412	0.981	2.02	0.7048	104.7	121	620
BERYLLIUM	58	57	nonparametric (assume lognormal)	0.2852	0.8382	0.981	1.875	0.5078	0.86	0.92	8.20
CADMIUM	81	80	nonparametric (assume lognormal)	0.1958	0.8785	0.985	3.1242	1.7869	8.10	7.70	293
CALCIUM	58	57	nonparametric (assume lognormal)	0.4827	0.9376	0.981	2.6585	1.3320	6,947	9,426	74,000
CHROMIUM	58	57	nonparametric (assume lognormal)	0.1978	0.7496	0.981	2.5769	1.2631	169	95.2	3,840
COBALT	58	57	nonparametric (assume lognormal)	0.8749	0.9745	0.981	1.8059	0.3979	9.71	10.7	24.8
COPPER	70	69	nonparametric (assume lognormal)	0.3199	0.8118	0.983	3.2857	1.8773	381	396	7,050
CYANIDE	40	39	nonparametric (assume lognormal)	0.2411	0.6061	0.94	2.2329	0.8702	1.03	0.91	20.4
IRON	58	57	nonparametric (assume lognormal)	0.6149	0.9144	0.981	1.9531	0.6191	23,450	26,992	103,000
LEAD	81	80	nonparametric (assume lognormal)	0.4683	0.9403	0.985	3.0032	1.6871	153	230	2,060
MAGNESIUM	58	57	nonparametric (assume lognormal)	0.3481	0.8286	0.981	1.9237	0.5788	3,251	3,522	29,900
MANGANESE	58	57	lognormal	0.9054	0.9879	0.981	1.891	0.5311	507	583	1,240
MERCURY	58	57	nonparametric (assume lognormal)	0.5009	0.8667	0.981	2.3608	1.0640	0.12	0.14	0.98
NICKEL	58	57	nonparametric (assume lognormal)	0.4323	0.9028	0.981	2.0235	0.7089	16.9	18.7	143
POTASSIUM	58	57	nonparametric (assume lognormal)	0.8225	0.977	0.981	1.9837	0.6585	785	948	2,690
SELENIUM	52	51	nonparametric (assume lognormal)	0.1945	0.6363	0.98	1.8923	0.5246	0.54	0.54	7.30
SILVER	70	69	nonparametric (assume lognormal)	0.3475	0.8132	0.983	3.3736	1.9460	10.4	12.4	168
SODIUM	58	57	nonparametric (assume lognormal)	0.2232	0.8653	0.981	2.186	0.8918	140	134	2,910
THALLIUM	58	57	nonparametric (assume lognormal)	0.2013	0.7024	0.981	1.8675	0.4967	0.50	0.51	0.69
VANADIUM	58	57	nonparametric (assume lognormal)	0.2058	0.8198	0.981	1.9738	0.6457	39.6	41.4	586
ZINC	70	69	nonparametric (assume lognormal)	0.4349	0.898	0.983	2.9334	1.5950	386	535	5,640
1,1-DICHLOROETHANE	46	45	nonparametric (assume lognormal)	0.2426	0.5696	0.945	2.4987	1.1439	39.8	21.7	16.0
1,2-DICHLOROETHENE (TOTAL)	46	45	nonparametric (assume lognormal)	0.2458	0.5073	0.945	2.4922	1.1381	40.3	22.0	60.0
2-BUTANONE	46	45	nonparametric (assume lognormal)	0.2496	0.5428	0.945	2.4319	1.0850	42.8	25.5	24.0
2-HEXANONE	46	45	nonparametric (assume lognormal)	0.2419	0.554	0.945	2.4741	1.1222	40.3	22.9	2.00
4-METHYL-2-PENTANONE	46	45	nonparametric (assume lognormal)	0.2631	0.6234	0.945	2.5698	1.2065	42.5	27.6	110
ACETONE	46	45	nonparametric (assume lognormal)	0.437	0.9108	0.945	3.042	1.5851	64.8	109	170
BENZENE	46	45	nonparametric (assume lognormal)	0.2412	0.5715	0.945	2.5095	1.1534	39.7	21.7	8.00
BROMOMETHANE	45	44	nonparametric (assume lognormal)	0.2655	0.5184	0.945	2.3228	0.9823	23.6	17.1	360
CARBON DISULFIDE	46	45	nonparametric (assume lognormal)	0.2413	0.5521	0.945	2.4905	1.1367	39.7	21.4	10.0
CHLOROETHANE	46	45	nonparametric (assume lognormal)	0.2392	0.4828	0.945	2.4513	1.1022	39.8	21.0	3.00
CHLOROFORM	46	45	nonparametric (assume lognormal)	0.2419	0.6057	0.945	2.553	1.1917	39.5	22.0	4.00
CHLOROMETHANE	46	45	nonparametric (assume lognormal)	0.2263	0.5126	0.945	2.3503	1.0133	30.0	17.8	810
ETHYLBENZENE	46	45	nonparametric (assume lognormal)	0.2324	0.5308	0.945	2.457	1.1072	38.6	19.1	13.0
METHYLENE CHLORIDE	46	45	nonparametric (assume lognormal)	0.2327	0.7812	0.945	2.4857	1.1325	24.3	15.8	23.0
TETRACHLOROETHENE	46	45	nonparametric (assume lognormal)	0.2486	0.6423	0.945	2.5276	1.1693	40.5	23.9	23.0
TOLUENE	46	45	nonparametric (assume lognormal)	0.265	0.6708	0.945	2.6464	1.2718	41.9	26.2	150
TRANS-1,3-DICHLOROPROPENE	46	45	nonparametric (assume lognormal)	0.2591	0.5847	0.945	2.5629	1.2004	41.6	25.0	97.8
TRICHLOROETHENE	46	45	nonparametric (assume lognormal)	0.2443	0.6568	0.945	2.5578	1.1959	39.7	22.5	12.0
1,4-DICHLOROBENZENE	33	32	nonparametric (assume lognormal)	0.329	0.6513	0.931	2.1039	0.7097	374	403	68.0
3,3'-DICHLOROBENZIDINE	33	32	nonparametric (assume lognormal)	0.3286	0.6142	0.931	2.0738	0.6773	384	410	400
ACENAPHTHENE	33	32	nonparametric (assume lognormal)	0.3982	0.7307	0.931	2.1616	0.7682	416	471	1,400
ANTHRACENE	33	32	nonparametric (assume lognormal)	0.4408	0.7817	0.931	2.2028	0.8092	454	528	2,200
BENZO(A)ANTHRACENE	33	32	nonparametric (assume lognormal)	0.5394	0.8468	0.931	2.5728	1.1302	612	882	5,200
BENZO(A)PYRENE	33	32	nonparametric (assume lognormal)	0.5552	0.8417	0.931	2.5376	1.1018	556	810	3,800
BENZO(B)FLUORANTHENE	33	32	nonparametric (assume lognormal)	0.57	0.8382	0.931	2.5786	1.1349	639	941	4,900
BENZO(G,H,I)PERYLENE	33	32	nonparametric (assume lognormal)	0.6171	0.9054	0.931	2.2385	0.8427	338	451	2,100
BENZO(K)FLUORANTHENE	33	32	nonparametric (assume lognormal)	0.6413	0.9296	0.931	2.4003	0.9901	365	546	2,200
BIS(2-ETHYLHEXYL)PHTHALATE	34	33	lognormal	0.5269	0.9543	0.933	2.6533	1.2012	437	700	2,200

TABLE 6-14
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Substance	Number of Sample Results	Degrees of Freedom	Statistical Distribution of Site Data	Results of Shapiro-Wilk or Shapiro-Francia Distribution Tests			Table Value for $H_{0.90}$ (Lognorm.) or $T_{0.90}$ (Norm.)	Standard Deviation or Log Standard Deviation	Arithmetic Mean of All Site Results	Upper 95% Confidence Limit (UCL) on Mean	Maximum Positive Site Concentration
				W-norm	W-lognorm	W-Table					
BUTYL BENZYL PHTHALATE	33	32	nonparametric (assume lognormal)	0.3355	0.6955	0.931	2.1283	0.7344	371	406	110
CARBAZOLE	33	32	nonparametric (assume lognormal)	0.4065	0.7173	0.931	2.1654	0.7720	422	480	1,300
CHRYSENE	33	32	nonparametric (assume lognormal)	0.5592	0.8735	0.931	2.6432	1.1871	597	922	4,900
DI-N-BUTYL PHTHALATE	33	32	nonparametric (assume lognormal)	0.4184	0.8214	0.931	2.5322	1.0975	486	651	4,200
DIBENZO(A,H)ANTHRACENE	33	32	nonparametric (assume lognormal)	0.3451	0.7116	0.931	2.1214	0.7275	380	417	450
DIBENZOFURAN	33	32	nonparametric (assume lognormal)	0.3456	0.6816	0.931	2.1059	0.7118	383	417	570
DIETHYL PHTHALATE	33	32	nonparametric (assume lognormal)	0.3306	0.6659	0.931	2.1257	0.7318	373	409	48.0
FLUORANTHENE	33	32	nonparametric (assume lognormal)	0.466	0.8029	0.931	2.8322	1.3325	1,157	1,711	13,000
FLUORENE	33	32	nonparametric (assume lognormal)	0.4156	0.7955	0.931	2.2084	0.8145	419	498	1,000
INDENO(1,2,3-CD)PYRENE	33	32	nonparametric (assume lognormal)	0.4983	0.8841	0.931	2.4087	0.9976	472	636	2,500
NAPHTHALENE	33	32	nonparametric (assume lognormal)	0.3385	0.7136	0.931	2.1316	0.7378	372	408	250
PENTACHLOROPHENOL	33	32	nonparametric (assume lognormal)	0.3151	0.657	0.931	2.1693	0.7760	886	1,007	62.0
PHENANTHRENE	33	32	nonparametric (assume lognormal)	0.4454	0.8599	0.931	2.6726	1.2107	844	1,181	9,900
PYRENE	33	32	nonparametric (assume lognormal)	0.5076	0.837	0.931	2.8719	1.3620	1,009	1,640	9,800
ALDRIN	35	34	nonparametric (assume lognormal)	0.2614	0.3709	0.934	1.8764	0.4414	1.34	1.42	3.60
ALPHA-CHLORDANE	35	34	nonparametric (assume lognormal)	0.3406	0.4593	0.934	1.9271	0.5120	1.47	1.59	5.90
AROCLOR-1248	36	35	nonparametric (assume lognormal)	0.2878	0.3815	0.935	1.9	0.4784	27.5	29.1	110
AROCLOR-1254	36	35	nonparametric (assume lognormal)	0.189	0.387	0.935	2.106	0.7240	52.2	37.5	1,150
AROCLOR-1260	36	35	nonparametric (assume lognormal)	0.2774	0.383	0.935	2.39	0.9966	86.3	65.3	1,600
DIELDRIN	35	34	nonparametric (assume lognormal)	0.2834	0.4472	0.934	1.88	0.4464	2.69	2.87	5.80
ENDOSULFAN II	34	33	nonparametric (assume lognormal)	0.2775	0.3995	0.933	1.7693	0.2621	2.19	2.34	8.50
ENDOSULFAN SULFATE	35	34	nonparametric (assume lognormal)	0.2847	0.3905	0.934	1.896	0.4693	2.73	2.90	9.30
ENDRIN	35	34	nonparametric (assume lognormal)	0.4237	0.4943	0.934	2.1101	0.7242	3.96	4.46	20.0
ENDRIN KETONE	35	34	nonparametric (assume lognormal)	0.2657	0.4545	0.934	1.8757	0.4403	2.60	2.75	5.50
GAMMA-BHC (LINDANE)	35	34	nonparametric (assume lognormal)	0.2503	0.3998	0.934	1.8611	0.4195	1.32	1.39	2.50
GAMMA-CHLORDANE	33	32	nonparametric (assume lognormal)	0.2936	0.4245	0.931	1.8974	0.4642	1.40	1.50	3.40
HEPTACHLOR EPOXIDE	35	34	nonparametric (assume lognormal)	0.2596	0.3708	0.934	1.8749	0.4392	1.34	1.42	3.50
HEXAVALENT CHROMIUM	10	9	lognormal	0.8257	0.8837	0.842	3.9063	1.3677	0.0011	0.0084	0.0036
4,4'-DDE	35	34	nonparametric (assume lognormal)	0.2532	0.3884	0.934	2.1623	0.7777	5.04	4.45	82.0
4,4'-DDT	34	33	nonparametric (assume lognormal)	0.244	0.4744	0.933	2.319	0.9222	7.62	6.16	150
XYLENES, TOTAL	46	45	nonparametric (assume lognormal)	0.2365	0.4971	0.945	2.4361	1.0867	39.6	20.7	38.0
OCDD	5	4	lognormal	0.9235	0.9575	0.762	3.3971	0.6294	0.38	1.15	0.68
OCDF	5	4	lognormal	0.8615	0.9823	0.762	5.3056	1.0914	0.10	2.01	0.25
4,4'-DDD	35	34	nonparametric (assume lognormal)	0.2973	0.3976	0.934	2.079	0.6914	3.93	3.92	45.0
2-METHYLNAPHTHALENE	33	32	nonparametric (assume lognormal)	0.335	0.664	0.931	2.0892	0.6944	379	406	360

Notes:
Bold Text Indicates selected COPC for this media.
Units are mg/kg for Inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.
Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.
A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.
A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.
H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.
Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).
The representative concentration is select ed as the lowr of the 95% UCL on the mean and the maximum positive site concentration.

TABLE 6-15
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 3 SURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Substance	Number of Sample Results	Number of Detections	Statistical Distribution (at the 95% level)	Results of Shapiro-Wilk & Shapiro-Francia Distribution Tests: W-norm	W-lognorm	W-table	Table Value for Student's t (or H-value)	Standard Deviation of Log Sample Distribution	Arithmetic Mean of All Sample Results	95% UCL of Representative Limit (Log Scale Mean)	Maximum Positive Site Concentration
ALUMINUM	5	4	lognormal	0.9229	0.9593	0.762	2.2042	1.2251	9560	12000.2929	12800
ARSENIC	5	4	lognormal	0.8983	0.9118	0.762	2.5067	1.4078	5.9	9.1806	7.9
BARIUM	5	4	lognormal	0.8629	0.8645	0.762	2.1754	1.2045	83.3	102.3559	99
BERYLLIUM	5	4	lognormal	0.9316	0.9367	0.762	2.9497	1.0716	0.88	0.9749	0.97
CALCIUM	5	4	normal	0.9415	0.7928	0.762	2.132	9620.869	18732	27905.1078	30700
CHROMIUM	5	4	lognormal	0.9732	0.9732	0.762	2.4723	1.3885	25.68	38.9819	36.8
COBALT	5	4	lognormal	0.9292	0.9567	0.762	2.116	1.1615	9.38	11.0121	11.7
COPPER	5	4	lognormal	0.9249	0.9656	0.762	3.1034	1.7263	23.04	55.3865	42.3
CYANIDE	2	1	nonparametric (assume lognormal)	—	—	—	4.2892	1	0.385	3.1461	0.51
IRON	5	4	lognormal	0.9244	0.9463	0.762	2.3414	1.3104	20560	28406.1576	28600
LEAD	5	4	lognormal	0.9312	0.9602	0.762	2.1876	1.2137	23.14	28.6973	30.4
MAGNESIUM	5	4	normal	0.9461	0.8384	0.762	2.132	3320.9983	8476	11642.437	12300
MANGANESE	5	4	lognormal	0.9005	0.95	0.762	2.7242	1.5292	701	1270.1692	1180
NICKEL	5	4	normal	0.9329	0.9207	0.762	2.132	6.1487	14.93	20.7926	21.5
POTASSIUM	5	4	normal	0.6797	0.87	0.762	2.132	833.1629	1670	2464.387	2510
SODIUM	5	4	lognormal	0.5992	0.8619	0.762	7.1991	4.3129	861.4	213194.0931	3620
THALLIUM	5	4	lognormal	0.7161	0.8	0.762	3.2324	1	0.489	1.2724	1.1
VANADIUM	5	4	normal	0.9095	0.9957	0.762	2.132	12.2104	34.6	46.2422	50.7
ZINC	5	4	lognormal	0.7369	0.8725	0.762	3.352	1.854	71.58	204.2852	187
1,1,2,2-TETRACHLOROETHANE	1	0	nonparametric (assume lognormal)	—	—	—	0	1	1	0	1
BROMOMETHANE	1	0	nonparametric (assume lognormal)	—	—	—	0	1	21	0	21
ACENAPHTHYLENE	8	7	lognormal	0.6151	0.8333	0.818	5.162	1.7227	545.875	13840.5733	120
ANTHRACENE	13	12	nonparametric (assume lognormal)	0.514	0.7599	0.866	2.9703	1.5158	417.2308	882.6122	220
BENZO(A)ANTHRACENE	13	12	normal	0.9568	0.8248	0.866	1.782	337.1319	619.6923	786.3156	1200
BENZO(A)PYRENE	13	12	normal	0.9327	0.8587	0.866	1.782	599.8231	907.0769	1203.5322	1400
BENZO(B)FLUORANTHENE	8	7	normal	0.9803	0.9026	0.818	1.895	378.1133	693.75	947.0797	1300
BENZO(G,H,I)PERYLENE	8	7	lognormal	0.6451	0.8522	0.818	4.3145	1.7486	599.875	5273.3236	320
BENZO(K)FLUORANTHENE	8	7	lognormal	0.8858	0.9024	0.818	3.8187	2.7784	888.625	5550.0196	1000
CHRYSENE	8	7	normal	0.956	0.8878	0.818	1.895	386.887	621.125	880.333	1200
DIBENZO(A,H)ANTHRACENE	8	7	lognormal	0.7235	0.9071	0.818	4.9535	1.6843	642.125	14548.4035	99
FLUORANTHENE	13	12	normal	0.9711	0.7904	0.866	1.782	860.7793	1599.2308	2024.6605	3300
FLUORENE	8	7	lognormal	0.7639	0.928	0.818	5.1523	1.3095	673.625	22736.8329	41
INDENO(1,2,3-CD)PYRENE	8	7	lognormal	0.6694	0.9095	0.818	4.4533	2.091	612.875	6709.4745	380
PHENANTHRENE	8	7	lognormal	0.8694	0.9442	0.818	4.0309	3.0171	661.25	5265.179	1100
PYRENE	8	7	normal	0.9523	0.8631	0.818	1.895	590.3994	950	1345.5579	1800
GAMMA-BHC (LINDANE)	4	3	normal	0.877	0.8649	0.748	2.353	0.7761	1.5625	2.4756	2.5
4,4'-DDT	4	3	lognormal	0.8577	0.8834	0.748	9.3281	1.697	6.45	2030.6198	15

Notes:
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Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.
Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.
A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.
A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.
H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.
Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).
The representative concentration is select ed as the lowr of the 95% UCL on the mean and the maximum positive site concentration.

TABLE 6-16
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ALUMINUM	29	28	lognormal	0.8111	0.9492	0.926	1.7953	1.3354	12,725	14,010	29,500
ANTIMONY	29	28	nonparametric(assume logmormal)	0.7722	0.7861	0.926	2.3944	3.7326	5.41	9.67	16.6
ARSENIC	29	28	lognormal	0.8396	0.9352	0.926	2.0974	1.8200	5.02	6.74	17.6
BARIUM	29	28	lognormal	0.7100	0.9720	0.926	2.3005	2.2786	289	419	1,530
BERYLLIUM	29	28	lognormal	0.8750	0.9803	0.926	1.9442	1.4785	1.12	1.36	3.1
CADMIUM	29	28	nonparametric(assume logmormal)	0.6017	0.8655	0.926	3.6418	3.6618	7.96	32.9	67.1
CALCIUM	29	28	lognormal	0.7848	0.9640	0.926	2.7146	3.3195	10,744	22,175	42,500
CHROMIUM	29	28	nonparametric(assume logmormal)	0.8517	0.9100	0.926	2.0355	1.6617	30.8	39.7	83.4
COBALT	29	28	lognormal	0.8733	0.9493	0.926	1.8638	1.4393	10.7	12.3	23.4
COPPER	29	28	nonparametric(assume logmormal)	0.4874	0.9108	0.926	3.7099	6.3364	332	1,390	3,760
IRON	29	28	lognormal	0.7728	0.9564	0.926	1.8688	1.4978	23,293	26,714	69,500
LEAD	35	34	nonparametric(assume logmormal)	0.4384	0.9276	0.934	3.5840	6.4163	330	1,016	4,570
MAGNESIUM	29	28	lognormal	0.8887	0.9530	0.926	2.0397	1.8069	5,588	7,149	15,600
MANGANESE	29	28	lognormal	0.8182	0.9690	0.926	2.2475	2.2750	733	1,073	2,330
MERCURY	29	28	nonparametric(assume logmormal)	0.5944	0.8766	0.926	3.9971	3.7316	1.26	8.20	9.7
NICKEL	29	28	nonparametric(assume logmormal)	0.5645	0.8521	0.926	2.2765	2.3350	34.5	44.7	230
POTASSIUM	29	28	lognormal	0.8226	0.9816	0.926	1.9729	1.7136	1,154	1,407	3,710
SELENIUM	29	28	nonparametric(assume logmormal)	0.5020	0.7656	0.926	2.0339	2.0032	0.58	0.68	2.9
SILVER	29	28	nonparametric(assume logmormal)	0.5093	0.8312	0.926	4.4838	5.7189	34.0	462	368
SODIUM	29	28	lognormal	0.7631	0.9754	0.926	2.2575	2.2773	342	486	1,460
THALLIUM	29	28	nonparametric(assume logmormal)	0.6225	0.8240	0.926	1.8881	1.1859	0.41	0.47	1.4
VANADIUM	29	28	lognormal	0.5432	0.9290	0.926	2.0804	1.9318	47.7	59.0	284
ZINC	29	28	nonparametric(assume logmormal)	0.4416	0.8907	0.926	3.4308	5.4471	725	1,970	9,100
1,2-DICHLOROETHENE (TOTAL)	29	28	nonparametric(assume logmormal)	0.3670	0.4864	0.926	3.2829	1.0000	107	93.4	4
2-BUTANONE	29	28	nonparametric(assume logmormal)	0.3853	0.5634	0.926	3.2937	5.3813	119	128	1,000
ACETONE	29	28	nonparametric(assume logmormal)	0.4165	0.8940	0.926	3.1595	2.9755	117	223	140
BENZENE	29	28	nonparametric(assume logmormal)	0.3665	0.4644	0.926	3.2616	1.0000	107	92.6	5.1
CARBON DISULFIDE	29	28	nonparametric(assume logmormal)	0.3685	0.5626	0.926	3.3490	2.3193	107	102	13
CHLOROBENZENE	29	28	nonparametric(assume logmormal)	0.3889	0.5439	0.926	3.3806	6.0418	112	127	140
CHLOROFORM	29	28	nonparametric(assume logmormal)	0.3683	0.5907	0.926	3.4233	1.0000	107	109	1
ETHYLBENZENE	29	28	nonparametric(assume logmormal)	0.3938	0.5822	0.926	3.3964	6.0241	113	141	130
METHYLENE CHLORIDE	29	28	nonparametric(assume logmormal)	0.3078	0.6604	0.926	3.4138	1.0000	177	159	3,300
TOLUENE	29	28	nonparametric(assume logmormal)	0.3893	0.6761	0.926	3.5537	3.7412	111	148	120
1,4-DICHLOROBENZENE	20	19	nonparametric(assume logmormal)	0.3561	0.6938	0.905	3.2118	1.8064	1,519	2,502	120
ACENAPHTHENE	26	25	nonparametric(assume logmormal)	0.3763	0.8596	0.920	3.4205	3.6663	1,422	3,646	4,400
ACENAPHTHYLENE	26	25	nonparametric(assume logmormal)	0.4173	0.8846	0.920	3.5758	2.8977	1,556	4,063	1,200
ANTHRACENE	26	25	nonparametric(assume logmormal)	0.4178	0.9109	0.920	4.2988	8.7007	2,154	21,351	21,000
BENZO(A)ANTHRACENE	26	25	lognormal	0.3717	0.9526	0.920	4.3271	10.6676	3,725	37,125	53,000
BENZO(A)PYRENE	26	25	lognormal	0.4033	0.9628	0.920	4.1346	9.0518	3,407	24,550	44,000
BENZO(B)FLUORANTHENE	26	25	lognormal	0.4152	0.9597	0.920	4.2769	10.6721	3,578	35,976	45,000
BENZO(G,H,I)PERYLENE	26	25	nonparametric(assume logmormal)	0.3936	0.8658	0.920	4.1666	4.6465	2,251	15,030	26,000
BENZO(K)FLUORANTHENE	26	25	lognormal	0.3980	0.9290	0.920	4.3792	7.9912	2,751	32,962	34,000
BIS(2-ETHYLHEXYL)PHTHALATE	20	19	nonparametric(assume logmormal)	0.4120	0.8306	0.905	3.6630	6.5560	1,682	5,094	4,000
BUTYL BENZYL PHTHALATE	20	19	nonparametric(assume logmormal)	0.3561	0.6986	0.905	3.2109	1.0000	1,525	2,566	41
CARBAZOLE	20	19	nonparametric(assume logmormal)	0.3531	0.7706	0.905	3.1873	3.7346	1,505	2,492	1,000
CHRYSENE	26	25	lognormal	0.3825	0.9443	0.920	4.3267	10.6276	3,703	38,764	51,000
DI-N-BUTYL PHTHALATE	20	19	nonparametric(assume logmormal)	0.3636	0.8638	0.905	3.7719	1.0276	1,482	4,562	53
DI-N-OCTYL PHTHALATE	20	19	nonparametric(assume logmormal)	0.3536	0.6083	0.905	3.0690	1.0000	1,539	2,254	320
DIBENZO(A,H)ANTHRACENE	26	25	nonparametric(assume logmormal)	0.4108	0.8792	0.920	4.1015	5.1696	1,544	9,291	9,400
DIBENZOFURAN	20	19	nonparametric(assume logmormal)	0.3589	0.7427	0.905	3.2218	1.9956	1,522	2,553	300
DIETHYL PHTHALATE	20	19	nonparametric(assume logmormal)	0.3541	0.6355	0.905	3.1399	1.0000	1,524	2,333	86
FLUORANTHENE	26	25	lognormal	0.2868	0.9658	0.920	4.3942	11.1333	6,677	64,827	120,000

TABLE 6-16
REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMISTER, PENNSYLVANIA

Subsurface	Number of Samples	Number of Detects	Statistical Distribution of the Data	Results of Shapiro-Wilk Statistical Distribution Test			Arithmetic Mean (Conc.)	Standard Deviation	Upper 95% Confidence Limit (UCL) on Mean	Maximum Detected Conc.	Representative Site Concentration
				W-norm.	W-lognorm.	W-table					
FLUORENE	26	25	nonparametric(assume logmormal)	0.3745	0.8667	0.920	3.9889	4.0051	1,405	9,115	4,500
HEXACHLOROETHANE	20	19	nonparametric(assume logmormal)	0.3577	0.6367	0.905	3.0755	1.0000	1,555	2,360	640
INDENO(1,2,3-CD)PYRENE	26	25	nonparametric(assume logmormal)	0.4043	0.9052	0.920	3.8858	7.9466	2,476	10,710	29,000
NAPHTHALENE	26	25	nonparametric(assume logmormal)	0.4059	0.8116	0.920	3.4588	1.6120	1,560	3,875	450
PHENANTHRENE	26	25	lognormal	0.3547	0.9374	0.920	4.3009	10.9532	4,634	36,617	71,000
PHENOL	20	19	nonparametric(assume logmormal)	0.3531	0.6025	0.905	3.0939	1.0000	1,530	2,257	150
PYRENE	26	25	lognormal	0.2917	0.9563	0.920	4.1385	8.9916	5,541	36,810	97,000
ALDRIN	12	11	nonparametric(assume logmormal)	0.4138	0.8087	0.859	4.2795	5.6359	19.4	123	180
AROCLOR-1242	19	18	nonparametric(assume logmormal)	0.3822	0.5735	0.901	2.3420	1.8205	46.3	56.7	84
AROCLOR-1248	19	18	nonparametric(assume logmormal)	0.4017	0.5520	0.901	2.3820	1.0000	47.7	61.7	120
AROCLOR-1254	19	18	nonparametric(assume logmormal)	0.2916	0.7049	0.901	3.4970	5.3409	381	597	5,900
AROCLOR-1260	19	18	nonparametric(assume logmormal)	0.5570	0.6581	0.901	2.6907	2.4100	70.8	118	290
ENDRIN	13	12	nonparametric(assume logmormal)	0.5773	0.7428	0.866	2.9344	2.0988	7.26	15.7	24
GAMMA-BHC (LINDANE)	12	11	nonparametric(assume logmormal)	0.4704	0.6754	0.859	2.8280	1.0000	3.07	5.79	3.5
GAMMA-CHLORDANE	13	12	nonparametric(assume logmormal)	0.5823	0.6351	0.866	3.1071	1.4854	3.98	9.68	14
HEPTACHLOR EPOXIDE	13	12	nonparametric(assume logmormal)	0.4947	0.6563	0.866	2.8107	1.0000	3.11	5.81	6.1
4,4'-DDE	13	12	nonparametric(assume logmormal)	0.7394	0.7830	0.866	3.3770	1.5892	11.7	44.7	42
4,4'-DDT	13	12	nonparametric(assume logmormal)	0.6769	0.7754	0.866	3.1612	1.7197	9.11	26.1	31
XYLENES, TOTAL	29	28	nonparametric(assume logmormal)	0.4433	0.6145	0.926	3.5719	9.5637	130	220	580
OCDD	4	3	lognormal	0.8618	0.9695	0.748	8.8176	2.1203	0.95	164	2.2
4,4'-DDD	12	11	nonparametric(assume logmormal)	0.7156	0.8026	0.859	4.6603	3.1538	37.9	755	150
2-METHYLNAPHTHALENE	20	19	nonparametric(assume logmormal)	0.3629	0.7389	0.905	3.2196	2.6978	1,538	2,640	690

Notes:
Bold Text indicates selected COPC for this media.
Units are mg/kg for inorganics, ug/kg for organics.
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.
Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.
A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.
A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.
H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.
Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).
The representative concentration is select ed as the lowr of the 95% UCL on the mean and the maximum positive site concentration.

TABLE 6-17

REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)

NAWC WARMISTER, PENNSYLVANIA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1,1,2,2-TETRACHLOROETHANE	59	58	nonparametric (assumed lognorm.)	0.3501	0.4894	0.981	2.9064	1	95.0424	63.1611	2
1,2-DICHLOROETHENE (TOTAL)	59	58	nonparametric (assumed lognorm.)	0.3506	0.5131	0.981	2.925	5.4497	95.0932	64.9623	11
2-BUTANONE	59	58	nonparametric (assumed lognorm.)	0.3446	0.5021	0.981	2.8602	2.1723	87.7627	59.6469	23
4-METHYL-2-PENTANONE	59	58	nonparametric (assumed lognorm.)	0.3765	0.4656	0.981	2.965	1	101.7119	73.7185	450
ACETONE	59	58	nonparametric (assumed lognorm.)	0.3167	0.8989	0.981	3.3972	4.1136	264.5763	423.0068	1100
CHLOROMETHANE	59	58	nonparametric (assumed lognorm.)	0.358	0.4936	0.981	2.8387	1	79.0169	55.0479	2
ETHYLBENZENE	59	58	nonparametric (assumed lognorm.)	0.345	0.4462	0.981	2.869	1	94.322	58.7671	14
TETRACHLOROETHENE	59	58	nonparametric (assumed lognorm.)	0.3476	0.4479	0.981	2.8822	1	94.7627	60.489	10
TOLUENE	59	58	nonparametric (assumed lognorm.)	0.3497	0.4666	0.981	2.8884	1	95.1271	62.5042	8
TRICHLOROETHENE	59	58	nonparametric (assumed lognorm.)	0.3465	0.5165	0.981	2.922	2.3677	94.1102	60.7304	15
2-METHYLNAPHTHALENE	30	29	nonparametric (assumed lognorm.)	0.3642	0.5992	0.927	2.029	1	293.9667	339.0709	44
4-METHYLPHENOL	30	29	nonparametric (assumed lognorm.)	0.338	0.4797	0.927	1.9635	1	297.3333	326.0525	160
ACENAPHTHYLENE	30	29	nonparametric (assumed lognorm.)	0.2954	0.464	0.927	1.923	1	284.5	307.9141	560
ANTHRACENE	30	29	nonparametric (assumed lognorm.)	0.289	0.4604	0.927	1.9189	1	282.8333	305.3931	510
BENZO(A)ANTHRACENE	30	29	nonparametric (assumed lognorm.)	0.3866	0.7398	0.927	2.2043	4.8147	317.0667	374.1338	2700
BENZO(A)PYRENE	30	29	nonparametric (assumed lognorm.)	0.3718	0.7106	0.927	2.2159	4.9529	340.6	393.5448	3000
BENZO(B)FLUORANTHENE	30	29	nonparametric (assumed lognorm.)	0.378	0.7317	0.927	2.2289	4.5635	351.8333	409.6367	2800
BENZO(G,H,I)PERYLENE	30	29	nonparametric (assumed lognorm.)	0.3891	0.6671	0.927	2.0986	4.4948	272.1667	326.1757	1700
BENZO(K)FLUORANTHENE	30	29	nonparametric (assumed lognorm.)	0.522	0.7436	0.927	1.963	3.366	250.0667	298.1644	1100
BIS(2-ETHYLHEXYL)PHTHALATE	30	29	nonparametric (assumed lognorm.)	0.4437	0.8664	0.927	2.3601	1.8773	224.6333	291.7136	320
CHRYSENE	30	29	nonparametric (assumed lognorm.)	0.3605	0.6805	0.927	2.2112	4.9042	357.0333	397.7156	3300
DIBENZO(A,H)ANTHRACENE	30	29	nonparametric (assumed lognorm.)	0.358	0.5167	0.927	1.9663	1	305.8333	338.1086	400
DI-N-BUTYL PHTHALATE	30	29	nonparametric (assumed lognorm.)	0.3576	0.6558	0.927	2.0582	1.3899	272.6	313.9823	110
FLUORANTHENE	30	29	nonparametric (assumed lognorm.)	0.3587	0.7155	0.927	2.3019	4.3685	395.5333	448.0904	3700
FLUORENE	30	29	nonparametric (assumed lognorm.)	0.2546	0.4046	0.927	1.9012	1	273.8333	291.5153	240
INDENO(1,2,3-CD)PYRENE	30	29	nonparametric (assumed lognorm.)	0.48	0.7563	0.927	2.1463	4.6422	255.6	331.4425	1300
PENTACHLOROPHENOL	30	29	nonparametric (assumed lognorm.)	0.3341	0.5414	0.927	2.0035	1	696.8333	788.7723	120
PHENANTHRENE	30	29	nonparametric (assumed lognorm.)	0.4028	0.6983	0.927	2.0389	4.234	277.1333	321.7499	1900
PYRENE	30	29	nonparametric (assumed lognorm.)	0.3202	0.6674	0.927	2.4559	5.5038	531.8333	544.7862	7000
4,4'-DDD	30	29	nonparametric (assumed lognorm.)	0.3908	0.8107	0.927	3.091	11.1555	13.067	20.8118	150
4,4'-DDE	30	29	nonparametric (assumed lognorm.)	0.3707	0.6473	0.927	2.1392	2.6506	2.802	3.542	3.7
4,4'-DDT	30	29	nonparametric (assumed lognorm.)	0.379	0.6633	0.927	2.4424	4.6951	6.8037	7.6698	78
ALDRIN	30	29	nonparametric (assumed lognorm.)	0.3202	0.4413	0.927	1.9507	1	1.5367	1.6774	2.3
ALPHA-CHLORDANE	30	29	nonparametric (assumed lognorm.)	0.3184	0.5201	0.927	2.0008	1	1.47	1.6571	0.25
AROCLOR-1242	30	29	nonparametric (assumed lognorm.)	0.3027	0.4138	0.927	1.9373	1	29.25	31.7084	31
AROCLOR-1254	30	29	nonparametric (assumed lognorm.)	0.3557	0.5476	0.927	1.9511	1.4251	30.6	33.7503	44
AROCLOR-1260	30	29	nonparametric (assumed lognorm.)	0.2709	0.4602	0.927	2.2651	4.6344	60.3667	55.1556	930
DELTA-BHC	30	29	nonparametric (assumed lognorm.)	0.349	0.5837	0.927	2.28	34.2067	1.6046	2.1692	9.9
DIELDRIN	30	29	nonparametric (assumed lognorm.)	0.3712	0.6388	0.927	2.6567	12.6327	2.5748	5.5429	21
ENDOSULFAN I	30	29	nonparametric (assumed lognorm.)	0.3298	0.5333	0.927	2.1345	5.5432	1.454	1.8534	0.8
ENDOSULFAN II	30	29	nonparametric (assumed lognorm.)	0.363	0.6013	0.927	2.3328	10.8163	3.1263	4.4984	19
ENDRIN	30	29	nonparametric (assumed lognorm.)	0.4799	0.6044	0.927	2.295	11.7011	2.6005	4.1178	13
ENDRIN ALDEHYDE	30	29	nonparametric (assumed lognorm.)	0.3147	0.5021	0.927	1.9797	1	2.836	3.1491	0.63
ENDRIN KETONE	30	29	nonparametric (assumed lognorm.)	0.4142	0.5664	0.927	2.2168	12.9204	2.486	3.6468	13
GAMMA-BHC (LINDANE)	30	29	nonparametric (assumed lognorm.)	0.3626	0.6474	0.927	2.2106	1.241	1.406	1.8678	0.19
GAMMA-CHLORDANE	30	29	nonparametric (assumed lognorm.)	0.3484	0.5649	0.927	2.1874	10.142	1.6039	2.075	13
HEPTACHLOR	30	29	nonparametric (assumed lognorm.)	0.328	0.5167	0.927	2.1531	8.2204	1.4654	1.91	1.2
HEPTACHLOR EPOXIDE	30	29	nonparametric (assumed lognorm.)	0.3477	0.5869	0.927	2.2459	1	1.4301	2.0043	0.059
METHOXYCHLOR	30	29	nonparametric (assumed lognorm.)	0.3888	0.8529	0.927	2.7697	1	13.6242	32.9645	0.81
ALUMINUM	65	64	nonparametric (assumed lognorm.)	0.9722	0.9064	0.982	1.7786	1.4237	11340.3077	12360.9506	20100
ANTIMONY	39	38	nonparametric (assumed lognorm.)	0.3911	0.9165	0.939	2.98	5.3989	10.1781	21.1093	144

TABLE 6-17

REPRESENTATIVE CONCENTRATION AND STATISTICAL DISTRIBUTION - IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)

NAWC WARMISTER, PENNSYLVANIA

Chemical Summary	Number of Samples Analyzed	Number of Detections	Statistical Distribution Selected	Results of Shapiro-Wilk Test for Normality: W-norm	W-lognorm	W-table	Student's t-value or H-value	Arithmetic Mean Detection + Half DL	Standard Deviation	95% UCL of Arithmetic Mean	Maximum Site Concentration
ARSENIC	65	64	lognormal	0.8446	0.986	0.982	2.1973	1.9602	1.7578	2.3317	6.4
BARIUM	65	64	nonparametric (assumed lognorm.)	0.7736	0.9565	0.982	1.8188	1.5352	101.1492	110.5436	316
BERYLLIUM	65	64	nonparametric (assumed lognorm.)	0.5427	0.9439	0.982	1.913	1.6458	1.0373	1.1586	6.7
CADMIUM	65	64	nonparametric (assumed lognorm.)	0.2676	0.7769	0.982	3.1651	4.8075	4.4495	3.5567	91.1
CALCIUM	65	64	nonparametric (assumed lognorm.)	0.3172	0.7463	0.982	2.4657	3.2456	6993.6923	6067.9865	132000
CHROMIUM	65	64	nonparametric (assumed lognorm.)	0.3157	0.854	0.982	2.9988	5.1207	251.9215	243.5759	4730
COBALT	65	64	nonparametric (assumed lognorm.)	0.646	0.883	0.982	1.8429	1.5691	14.7792	16.4187	61.4
COPPER	65	64	nonparametric (assumed lognorm.)	0.2347	0.9742	0.982	2.7757	3.3987	27.3408	34.6661	707
CYANIDE	37	36	nonparametric (assumed lognorm.)	0.3546	0.7123	0.936	3.0609	4.8892	4.6677	5.4877	79.6
HEXAVALENT CHROMIUM	39	38	nonparametric (assumed lognorm.)	0.4143	0.8427	0.939	3.9855	2.3962	1.6125	16.3158	22.5
IRON	65	64	lognormal	0.7216	0.9827	0.982	1.9906	1.9713	19845.5385	23272.2467	91700
LEAD	65	64	nonparametric (assumed lognorm.)	0.691	0.9583	0.982	2.1867	2.1358	14.1322	19.1959	89.8
MAGNESIUM	65	64	nonparametric (assumed lognorm.)	0.345	0.9093	0.982	2.0453	2.1086	3766.9385	4270.514	42800
MANGANESE	65	64	nonparametric (assumed lognorm.)	0.6794	0.9767	0.982	2.1469	2.3686	1077.2354	1355.1399	6090
MERCURY	65	64	nonparametric (assumed lognorm.)	0.274	0.6686	0.982	2.3441	3.3466	0.137	0.1127	2.6
NICKEL	65	64	nonparametric (assumed lognorm.)	0.7424	0.8996	0.982	1.8336	1.5721	17.7338	19.735	62.7
POTASSIUM	65	64	nonparametric (assumed lognorm.)	0.8873	0.9678	0.982	2.177	2.4277	1517.7769	2029.8232	5680
SILVER	65	64	nonparametric (assumed lognorm.)	0.2069	0.6963	0.982	3.139	6.7292	11.448	7.2274	373
SODIUM	65	64	nonparametric (assumed lognorm.)	0.5303	0.7956	0.982	2.0121	2.3167	116.7969	127.4169	612
THALLIUM	65	64	nonparametric (assumed lognorm.)	0.6371	0.7778	0.982	1.7163	1	0.4676	0.4877	1.1
VANADIUM	65	64	nonparametric (assumed lognorm.)	0.9677	0.9747	0.982	1.8284	1.5592	17.8662	19.9363	33.7
ZINC	65	64	nonparametric (assumed lognorm.)	0.4876	0.9558	0.982	2.0828	1.9176	44.2123	52.1549	327

Notes:

Bold Text indicates selected COPC for this media.

Units are mg/kg for inorganics, ug/kg for organics.

Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result. Non-detected results are treated as present at one-half the detection limit in all calculations.

Statistical distribution of data is determined using Shapiro-Wilk test for n <= 50, Shapiro-Francia test for n > 50. Statistical significance level is 0.05.

A normal distribution is assumed if the test statistic W-norm. is >= the reference value (W-table) and W-norm. > W-lognorm.

A lognormal distribution is assumed if the test statistic W-lognorm. is >= the reference value (W-table) and W-lognorm. > W-norm. A lognormal distribution is also the default assumption if neither distribution passes the W-test.

H-values and standard deviations of log-transformed data are used to calculate the UCL if the data are assumed to be lognormally distributed. Student's t-values and standard deviations are used for normally distributed data sets.

Arithmetic mean includes positive detections and non-detected results (detection limits are divided by two).

The representative concentration is select ed as the lowr of the 95% UCL on the mean and the maximum positive site concentration.

As shown in these tables, the COPCs in surface soil and subsurface soil generally exhibited a lognormal or nonparametric (assumed lognormal) distribution better than a normal distribution, with the exception of the PAHs in Site 3 surface soil.

6.2.5 Exposure Point Concentrations

An EPC was calculated for each COPC selected for the various environmental media data sets. Post-remedial concentrations of detected chemicals in surface and subsurface soils were evaluated, along with pre-removal concentrations of detected substances in off-base sediment and off-base surface water. Usability of results is discussed below. The EPC was calculated using the latest risk assessment guidance from EPA (1985, 1989a, 1991a, 1991b, 1998a) and Gilbert (1987).

6.2.5.1 Calculation of Exposure Point Concentrations

Where available, validated data were used to calculate EPCs. The validated data for Area A were generated between 1991 and 1999 as part of RI field work. For purposes of calculating the EPC, a value of one-half the sample quantitation limit was assumed for non-detect (U, UJ, and UL qualified) results. Estimated values (J qualified), biased values (L and K qualified), and other qualified values (N and P qualified) were used as the reported value. Rejected (R and UR qualified) and blank-contamination (B and BJ qualified) values were eliminated from further consideration.

Duplicate samples were averaged together and considered as one result. For duplicates, where one result was positive and the other result was a non-detect, the problem of calculating an average result arose whenever half the detection limit exceeded the positive result. In these situations, the positive result was used to represent the duplicate pair.

The calculation of an EPC involves two steps. First, the distribution of the data was determined as discussed in the preceding section. Then, based on the distribution of the data, an EPC was either calculated or selected.

Several important assumptions were used to evaluate the distribution of the data (Section 6.2.4):

- The distribution of a data set was determined using a Shapiro-Wilk test.
- The distributions were classified as lognormal, normal, or unknown.
- By default, environmental data are generally determined to be lognormally distributed.

- If the data were not determined to be either a lognormal or normal distribution, they were classified as an unknown distribution and a lognormal distribution was assumed.

If the data were considered to be lognormally distributed, then the standard deviation of the log-transformed sample set was determined. The one-sided upper 95 percent confidence limit (UCL_{LOG}) was then calculated. The EPC was then selected as the lesser value of the one-sided 95 percent UCL and the maximum positive value in the data set.

If the data were determined to be normally distributed, then the standard deviation of the sample set was used to calculate the one-sided 95 percent UCL. The one-sided upper 95 percent confidence limit (UCL_{NOR}) was calculated. The EPC was then selected as the lesser value of the one-sided 95 percent UCL and the maximum positive value in the data set.

For small sample sets or sample sets in which all positive results equal less than one-half the detection limit, the UCL can sometimes exceed the maximum detected concentration. In these cases, the maximum concentration was selected as the EPC.

6.2.5.2 Reasonable Maximum Exposure EPCs

Reasonable maximum exposure (RME) EPCs were considered for use in the human health risk assessment. RME is the exposure that is expected to represent an upper-bound exposure in a given medium of interest. RME EPCs are selected from the maximum value, 95% upper confidence limit on the mean of normally distributed data (95% UCL-N), or the upper 95% upper confidence limit on log transformed data (95% UCL-T). As explained in Section 6.2.5.1, the RME EPC is the lower of the maximum value and the 95% UCL-N or 95% UCL-T (selected based on distribution of the data).

6.2.5.3 EPCs for Current/Future Industrial/Commercial Adults and Future Hypothetical Residential Children Surface Soil Exposure Pathways

Surface soil EPCs for the current/future industrial/commercial adult, and future residential child are shown in the following tables:

- Site 2 surface soil - Table 6-18
- Site 3 surface soil - Table 6-19

The calculated UCL-statistic was less than the reported maximum for all of the surface soil COPCs; therefore, RME EPCs for each of these contaminants was the 95% UCL-T statistic. The rationale for each

TABLE 6-18
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact (Ing. & Der.) with Surface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ALUMINUM	MG/KG	12,738	33,366	19,800		MG/KG	19,800	MAX	W<Wt;log def
ANTIMONY	MG/KG	2.18	3.81	10.8	J	MG/KG	3.81	95%UCL-T	W<Wt;log def
ARSENIC	MG/KG	5.40	7.10	13.1		MG/KG	7.10	95%UCL-T	Wno>=Wt & Wlg
BARIUM	MG/KG	119	224	452	J	MG/KG	224	95%UCL-T	W<Wt;log def
BERYLLIUM	MG/KG	0.94	1.06	1.4		MG/KG	1.06	95%UCL-N	Wno>=Wt & Wlg
CADMIUM	MG/KG	2.55	7.66	20.3	J	MG/KG	7.7	95%UCL-T	Wlg>=Wt & Wno
CALCIUM	MG/KG	19,443	42,064	215,000		MG/KG	42,064	95%UCL-T	Wlg>=Wt & Wno
CHROMIUM	MG/KG	46.6	87.6	133		MG/KG	87.6	95%UCL-T	W<Wt;log def
COBALT	MG/KG	11.0	16.6	14.5		MG/KG	14.5	MAX	W<Wt;log def
COPPER	MG/KG	114	161	1410		MG/KG	161	95%UCL-T	W<Wt;log def
IRON	MG/KG	22,818	25,933	38,000		MG/KG	25,933	95%UCL-N	Wno>=Wt & Wlg
LEAD	MG/KG	108	152	994	J	MG/KG	152	95%UCL-T	W<Wt;log def
MAGNESIUM	MG/KG	12,346	16,429	135,000		MG/KG	16,429	95%UCL-T	W<Wt;log def
MANGANESE	MG/KG	711	903	2,080		MG/KG	903	95%UCL-T	Wlg>=Wt & Wno
MERCURY	MG/KG	0.25	0.57	1.1	J	MG/KG	0.57	95%UCL-T	Wlg>=Wt & Wno
NICKEL	MG/KG	15.3	20.7	47		MG/KG	20.7	95%UCL-T	Wlg>=Wt & Wno
POTASSIUM	MG/KG	1,403	1,679	2,590		MG/KG	1,679	95%UCL-N	Wno>=Wt & Wlg
SELENIUM	MG/KG	0.47	0.61	1.6	J	MG/KG	0.61	95%UCL-T	W<Wt;log def
SILVER	MG/KG	3.83	23.3	58.4		MG/KG	23.3	95%UCL-T	W<Wt;log def
SODIUM	MG/KG	273	500	1,870	J	MG/KG	500	95%UCL-T	Wlg>=Wt & Wno
THALLIUM	MG/KG	0.51	0.68	1.4		MG/KG	0.68	95%UCL-T	W<Wt;log def
VANADIUM	MG/KG	39.1	46.0	119		MG/KG	46.0	95%UCL-T	W<Wt;log def
ZINC	MG/KG	319	428	4,800		MG/KG	428	95%UCL-T	W<Wt;log def
2-METHYLNAPHTHALENE	UG/KG	1,264	1,033	21,000	J	UG/KG	1,033	95%UCL-T	W<Wt;log def
ACENAPHTHENE	UG/KG	1,033	923	180	J	UG/KG	180	MAX	W<Wt;log def
ACENAPHTHYLENE	UG/KG	1,027	982	440	J	UG/KG	440	MAX	W<Wt;log def
ANTHRACENE	UG/KG	1,037	1,058	640	J	UG/KG	640	MAX	W<Wt;log def
BENZO(A)ANTHRACENE	UG/KG	1,413	2,198	3,300		UG/KG	2,198	95%UCL-T	W<Wt;log def
BENZO(A)PYRENE	UG/KG	1,433	2,590	3,400		UG/KG	2,590	95%UCL-T	Wlg>=Wt & Wno
BENZO(B)FLUORANTHENE	UG/KG	2,015	4,841	5,300		UG/KG	4,841	95%UCL-T	Wlg>=Wt & Wno
BENZO(G,H,I)PERYLENE	UG/KG	1,129	1,522	4,400	J	UG/KG	1,522	95%UCL-T	W<Wt;log def
BENZO(K)FLUORANTHENE	UG/KG	1,314	1,756	1,800		UG/KG	1,756	95%UCL-T	W<Wt;log def
BIS(2-ETHYLHEXYL)PHTHALATE	UG/KG	1,115	2,093	1,800		UG/KG	1,800	MAX	W<Wt;log def
CARBAZOLE	UG/KG	1,000	825	560	J	UG/KG	560	MAX	W<Wt;log def
CHRYSENE	UG/KG	1,633	3,009	3,300		UG/KG	3,009	95%UCL-T	W<Wt;log def

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TABLE 6-18
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact (Ing. & Der.) with Surface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
DI-N-BUTYL PHTHALATE	UG/KG	1,033	819	61	J	UG/KG	61.0	MAX	W<Wt;log def
DIBENZO(A,H)ANTHRACENE	UG/KG	994	979	470	J	UG/KG	470	MAX	W<Wt;log def
DIBENZOFURAN	UG/KG	1,022	958	73	J	UG/KG	73.0	MAX	W<Wt;log def
FLUORANTHENE	UG/KG	2,141	5,211	6,200		UG/KG	5,211	95%UCL-T	Wlg>=Wt & Wno
FLUORENE	UG/KG	997	782	250	J	UG/KG	250	MAX	W<Wt;log def
INDENO(1,2,3-CD)PYRENE	UG/KG	1,151	1,717	5,000	J	UG/KG	1,717	95%UCL-T	Wlg>=Wt & Wno
NAPHTHALENE	UG/KG	1,039	907	52	J	UG/KG	52.0	MAX	W<Wt;log def
PHENANTHRENE	UG/KG	1,511	2,742	3,700		UG/KG	2,742	95%UCL-T	W<Wt;log def
PYRENE	UG/KG	1,925	4,297	4,600		UG/KG	4,297	95%UCL-T	Wlg>=Wt & Wno
TOLUENE	UG/KG	6.08	8.04	2	J	UG/KG	2.00	MAX	W<Wt;log def
4,4'-DDD	UG/KG	3.28	4.57	19	J	UG/KG	4.57	95%UCL-T	W<Wt;log def
4,4'-DDE	UG/KG	3.08	4.54	7.9	J	UG/KG	4.54	95%UCL-T	W<Wt;log def
4,4'-DDT	UG/KG	5.32	10.3	23	J	UG/KG	10.3	95%UCL-T	W<Wt;log def
ALPHA-CHLORDANE	UG/KG	15.3	50.4	160		UG/KG	50.4	95%UCL-T	W<Wt;log def
AROCLOR-1254	UG/KG	284	596	3,700		UG/KG	596	95%UCL-T	W<Wt;log def
AROCLOR-1260	UG/KG	27.7	33.5	110	J	UG/KG	33.5	95%UCL-T	W<Wt;log def
DIELDRIN	UG/KG	5.08	9.05	32	J	UG/KG	9.05	95%UCL-T	W<Wt;log def
ENDRIN	UG/KG	35.4	123	370	J	UG/KG	123	95%UCL-T	W<Wt;log def
GAMMA-BHC (LINDANE)	UG/KG	2.65	4.84	5	J	UG/KG	4.84	95%UCL-T	W<Wt;log def
GAMMA-CHLORDANE	UG/KG	2.58	4.98	11	J	UG/KG	4.98	95%UCL-T	W<Wt;log def

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T) Mean of Normal Data (Mean-N).

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TABLE 6-19
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 3 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact (Ing. & Der.) with Surface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ALUMINUM	MG/KG	9,560.00	12,000.29	12800		MG/KG	12,000.29	95%UCL-T	Wlg>=Wt & Wno
ARSENIC	MG/KG	5.90	9.18	7.9		MG/KG	7.90	MAX	Max<U95log
BARIUM	MG/KG	83.30	102.36	99		MG/KG	99.00	MAX	Max<U95log
BERYLLIUM	MG/KG	0.88	0.97	0.97		MG/KG	0.97	MAX	Max<U95log
CALCIUM	MG/KG	18,732.00	27,905.11	30700		MG/KG	27,905.11	95%UCL-N	Wno>=Wt & Wlg
CHROMIUM	MG/KG	25.68	38.98	36.8		MG/KG	36.80	MAX	Max<U95log
COBALT	MG/KG	9.38	11.01	11.7		MG/KG	11.01	95%UCL-T	Wlg>=Wt & Wno
COPPER	MG/KG	23.04	55.39	42.3	J	MG/KG	42.30	MAX	Max<U95log
CYANIDE	MG/KG	0.39	3.15	0.51	J	MG/KG	0.51	MAX	Max<U95log
IRON	MG/KG	20,560.00	28,406.16	28600		MG/KG	28,406.16	95%UCL-T	Wlg>=Wt & Wno
LEAD	MG/KG	23.14	28.70	30.4		MG/KG	28.70	95%UCL-T	Wlg>=Wt & Wno
MAGNESIUM	MG/KG	8,476.00	11,642.44	12300		MG/KG	11,642.44	95%UCL-N	Wno>=Wt & Wlg
MANGANESE	MG/KG	701.00	1,270.17	1180	J	MG/KG	1,180.00	MAX	Max<U95log
NICKEL	MG/KG	14.93	20.79	21.5		MG/KG	20.79	95%UCL-N	Wno>=Wt & Wlg
POTASSIUM	MG/KG	1,670.00	2,464.39	2510		MG/KG	2,464.39	95%UCL-N	Wno>=Wt & Wlg
SODIUM	MG/KG	861.40	213,194.09	3620		MG/KG	3,620.00	MAX	Max<U95log
THALLIUM	MG/KG	0.49	1.27	1.1	J	MG/KG	1.10	MAX	Max<U95log
VANADIUM	MG/KG	34.60	46.24	50.7		MG/KG	46.24	95%UCL-N	Wno>=Wt & Wlg
ZINC	MG/KG	71.58	204.29	167		MG/KG	167.00	MAX	Max<U95log
ACENAPHTHYLENE	UG/KG	545.88	13,840.57	120	J	UG/KG	120.00	MAX	Max<U95log
ANTHRACENE	UG/KG	417.23	882.61	220	J	UG/KG	220.00	MAX	Max<U95log
BENZO(A)ANTHRACENE	UG/KG	619.69	786.32	1200		UG/KG	786.32	95%UCL-N	Wno>=Wt & Wlg
BENZO(A)PYRENE	UG/KG	907.08	1,203.53	1400		UG/KG	1,203.53	95%UCL-N	Wno>=Wt & Wlg
BENZO(B)FLUORANTHENE	UG/KG	693.75	947.08	1300		UG/KG	947.08	95%UCL-N	Wno>=Wt & Wlg
BENZO(G,H,I)PERYLENE	UG/KG	599.88	5,273.32	320	J	UG/KG	320.00	MAX	Max<U95log
BENZO(K)FLUORANTHENE	UG/KG	888.63	5,550.02	1000		UG/KG	1,000.00	MAX	Max<U95log
CHRYSENE	UG/KG	621.13	880.33	1200	J	UG/KG	880.33	95%UCL-N	Wno>=Wt & Wlg
DIBENZO(A,H)ANTHRACENE	UG/KG	642.13	14,548.40	99	J	UG/KG	99.00	MAX	Max<U95log
FLUORANTHENE	UG/KG	1,599.23	2,024.66	3300		UG/KG	2,024.66	95%UCL-N	Wno>=Wt & Wlg
FLUORENE	UG/KG	673.63	22,738.83	41	J	UG/KG	41.00	MAX	Max<U95log
INDENO(1,2,3-CD)PYRENE	UG/KG	612.88	6,709.47	380	J	UG/KG	380.00	MAX	Max<U95log
PHENANTHRENE	UG/KG	661.25	5,265.18	1100	J	UG/KG	1,100.00	MAX	Max<U95log
PYRENE	UG/KG	950.00	1,345.56	1800	J	UG/KG	1,345.56	95%UCL-N	Wno>=Wt & Wlg
1,1,2,2-TETRACHLOROETHANE	UG/KG	1.00	0.00	1	J	UG/KG	1.00	MAX	Max<U95log

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TABLE 6-19
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 3 SURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact (Ing. & Der.) with Surface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
BROMOMETHANE	UG/KG	21.00	0.00	21		UG/KG	21.00	MAX	Max<U95log
4,4'-DDT	UG/KG	6.45	2,030.62	15	J	UG/KG	15.00	MAX	Max<U95log
GAMMA-BHC (LINDANE)	UG/KG	1.56	2.48	2.5	J	UG/KG	2.48	95%UCL-N	Wno>=Wt & Wlg

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T) Mean of Normal Data (Mean-N).
J - Estimated Value

95% UCL-statistic was based on determination of the data distributional shape (normal, lognormal, nonparametric [assumed lognormal) and statistical scores that were presented in Tables 6-11 and 6-13.

6.2.5.4 EPCs for Current/Future Industrial/Commercial Adults and Future Hypothetical Residential Children Subsurface Soil Exposure Pathways

Subsurface soil EPCs for the current/future industrial/commercial adult and hypothetical future residential child are shown in the following tables:

- Site 1 subsurface soil - Table 6-20
- Site 2 subsurface soil - Table 6-21
- Site 3 subsurface soil - Table 6-22
- Impoundment Area subsurface soil - Table 6-23

The maximum detected concentration was less than the calculated UCL-statistic for dibenz(a,h)anthracene (Site 2) and silver (Site 3) in subsurface soil; therefore, the maximum detected concentrations were selected as the RME EPCs. The calculated UCL-statistic was less than the reported maximum for each of the remaining subsurface soil COPCs; therefore, RME EPCs were based on the 95% UCL-T statistic. The rationale for each 95% UCL-statistic was based on determination of the data distributional shape (normal, lognormal, nonparametric [assumed lognormal], and statistical scores that were presented in Tables 6-10, 6-12, 6-14, and 6-15.

6.2.5.5 EPCs for Current/Future Surface Water Exposure Pathway

Surface Water (total inorganics, dissolved inorganics, and organics) EPCs for the current/future recreational pre-adolescent (age 7 - 12) are shown in Tables 4-23, 4-23, and 4-24.

6.2.5.6 EPCs for Current/Future Sediment Exposure Pathways

Sediment EPCs for the recreational pre-adolescent (age 7 - 12) are shown in Tables 4-25 and 4-26.

6.3 RISK RATIO ANALYSIS

6.3.1 Cancer Effects

The maximum level of each COPC in two environmental media of concern, surface and subsurface soil, was compared to either an industrial or residential soil EPA Region III RBC, as appropriate. The potential

TABLE 6-20
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY SITE 1 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ALUMINUM	MG/KG	15,852	18,710	33500		MG/KG	18,710	95%UCL-T	W<Wt;log def
ANTIMONY	MG/KG	1.91	3.60	15.2	J	MG/KG	3.60	95%UCL-T	W<Wt;log def
ARSENIC	MG/KG	5.12	8.32	25.5		MG/KG	8.32	95%UCL-T	Wlg>=Wt & Wno
BARIUM	MG/KG	93	130	210		MG/KG	130	95%UCL-T	Wlg>=Wt & Wno
BERYLLIUM	MG/KG	1.40	2.03	3.1		MG/KG	2.03	95%UCL-T	Wlg>=Wt & Wno
CADMIUM	MG/KG	6.01	15.5	61.4		MG/KG	15.5	95%UCL-T	W<Wt;log def
CALCIUM	MG/KG	4,220	5,468	53400		MG/KG	5,468	95%UCL-T	W<Wt;log def
CHROMIUM	MG/KG	250	233	4600		MG/KG	233	95%UCL-T	W<Wt;log def
COBALT	MG/KG	17.2	25.8	66.1		MG/KG	25.8	95%UCL-T	Wlg>=Wt & Wno
COPPER	MG/KG	65.7	310	299	J	MG/KG	299	MAX	Max<U95log
CYANIDE	MG/KG	0.69	2.29	1.6		MG/KG	1.60	MAX	Max<U95log
IRON	MG/KG	38,462	53,412	251000		MG/KG	53,412	95%UCL-T	W<Wt;log def
LEAD	MG/KG	19.7	31.3	135		MG/KG	31.3	95%UCL-T	Wlg>=Wt & Wno
MAGNESIUM	MG/KG	3,084	6,769	5890		MG/KG	5,890	MAX	Max<U95log
MANGANESE	MG/KG	848	1,264	2630		MG/KG	1,264	95%UCL-T	Wlg>=Wt & Wno
MERCURY	MG/KG	0.47	0.46	6.8		MG/KG	0.46	95%UCL-T	W<Wt;log def
NICKEL	MG/KG	18.0	28.6	87.9		MG/KG	28.6	95%UCL-T	Wlg>=Wt & Wno
POTASSIUM	MG/KG	1,888	8,820	4600		MG/KG	4,600	MAX	Max<U95log
SELENIUM	MG/KG	0.72	1.29	3.3		MG/KG	1.29	95%UCL-T	Wlg>=Wt & Wno
SILVER	MG/KG	22.0	17	360		MG/KG	17	95%UCL-T	W<Wt;log def
SODIUM	MG/KG	134	226	707		MG/KG	226	95%UCL-T	Wlg>=Wt & Wno
THALLIUM	MG/KG	0.55	0.69	1.7		MG/KG	0.69	95%UCL-T	Wlg>=Wt & Wno
VANADIUM	MG/KG	30.1	38.4	66.6		MG/KG	38.4	95%UCL-T	Wlg>=Wt & Wno
ZINC	MG/KG	67.1	104	451		MG/KG	104	95%UCL-T	W<Wt;log def
2-BUTANONE	UG/KG	6.05	6.72	4.8	J	UG/KG	4.80	MAX	Max<U95log
4-METHYL-2-PENTANONE	UG/KG	5.52	2.91E+23	55	J	UG/KG	55.00	MAX	Max<U95log
4,4'-DDD	UG/KG	4.8	1,081	12	J	UG/KG	12.00	MAX	Max<U95log
4,4'-DDE	UG/KG	175.00	12.0	1.6	J	UG/KG	1.60	MAX	Max<U95log
AROCLOR-1254	UG/KG	22.1	27.1	41	J	UG/KG	27.1	95%UCL-T	W<Wt;log def
BIS(2-ETHYLHEXYL)PHTHALATE	UG/KG	3	316	40	J	UG/KG	40.0	MAX	Max<U95log
ENDRIN	UG/KG	28.53	97.9	4.8	J	UG/KG	4.80	MAX	Max<U95log
TOLUENE	UG/KG	8.15	17.1	2.9	J	UG/KG	2.90	MAX	Max<U95log

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).

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TABLE 6-20
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY SITE 1 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T)
Mean of Normal Data (Mean-N).
J - Estimated Value

TABLE 6-21
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ALUMINUM	MG/KG	15,500	16,637	133,000		MG/KG	16,637	95%UCL-T	W<Wt;log def
ANTIMONY	MG/KG	7.27	11.47	90.5	L	MG/KG	11.47	95%UCL-T	W<Wt;log def
ARSENIC	MG/KG	4.94	6.26	19.6		MG/KG	6.26	95%UCL-T	W<Wt;log def
BARIUM	MG/KG	104.7	121	620		MG/KG	121	95%UCL-T	W<Wt;log def
BERYLLIUM	MG/KG	0.86	0.92	8.20		MG/KG	0.92	95%UCL-T	W<Wt;log def
CADMIUM	MG/KG	8.10	7.70	293		MG/KG	7.70	95%UCL-T	W<Wt;log def
CALCIUM	MG/KG	6,947	9,426	74,000		MG/KG	9,426	95%UCL-T	W<Wt;log def
CHROMIUM	MG/KG	169	95.2	3,840		MG/KG	95	95%UCL-T	W<Wt;log def
COBALT	MG/KG	9.71	10.7	24.8		MG/KG	10.7	95%UCL-T	W<Wt;log def
COPPER	MG/KG	381	396	7,050		MG/KG	396	95%UCL-T	W<Wt;log def
CYANIDE	MG/KG	1.03	0.91	20.4		MG/KG	0.91	95%UCL-T	W<Wt;log def
IRON	MG/KG	23,450	26,992	103,000		MG/KG	26,992	95%UCL-T	W<Wt;log def
LEAD	MG/KG	153	230	2,060	J	MG/KG	230	95%UCL-T	W<Wt;log def
MAGNESIUM	MG/KG	3,251	3,522	29,900		MG/KG	3,522	95%UCL-T	W<Wt;log def
MANGANESE	MG/KG	507	583	1,240		MG/KG	583	95%UCL-T	Wlg>=Wt & Wno
MERCURY	MG/KG	0.12	0.14	0.98		MG/KG	0.14	95%UCL-T	W<Wt;log def
NICKEL	MG/KG	16.9	18.7	143		MG/KG	18.7	95%UCL-T	W<Wt;log def
POTASSIUM	MG/KG	785	948	2,690		MG/KG	948	95%UCL-T	W<Wt;log def
SELENIUM	MG/KG	0.54	0.54	7.30	J	MG/KG	0.54	95%UCL-T	W<Wt;log def
SILVER	MG/KG	10.4	12.4	168		MG/KG	12.4	95%UCL-T	W<Wt;log def
SODIUM	MG/KG	140	134	2,910		MG/KG	134	95%UCL-T	W<Wt;log def
THALLIUM	MG/KG	0.50	0.51	0.69	J	MG/KG	0.51	95%UCL-T	W<Wt;log def
VANADIUM	MG/KG	39.6	41.4	586		MG/KG	41.4	95%UCL-T	W<Wt;log def
ZINC	MG/KG	386	535	5,640		MG/KG	535	95%UCL-T	W<Wt;log def
1,1-DICHLOROETHANE	UG/KG	39.8	21.7	16.0		UG/KG	16.0	MAX	W<Wt;log def
1,2-DICHLOROETHENE (TOTAL)	UG/KG	40.3	22.0	60.0		UG/KG	22.0	95%UCL-T	W<Wt;log def
2-BUTANONE	UG/KG	42.8	25.5	24.0	J	UG/KG	24.0	MAX	W<Wt;log def
2-HEXANONE	UG/KG	40.3	22.9	2.00	J	UG/KG	2.00	MAX	W<Wt;log def
4-METHYL-2-PENTANONE	UG/KG	42.5	27.6	110		UG/KG	27.6	95%UCL-T	W<Wt;log def
ACETONE	UG/KG	64.8	109	170		UG/KG	109	95%UCL-T	W<Wt;log def
BENZENE	UG/KG	39.7	21.7	8.00		UG/KG	8.00	MAX	W<Wt;log def
BROMOMETHANE	UG/KG	23.6	17.1	360	J	UG/KG	17.1	95%UCL-T	W<Wt;log def
CARBON DISULFIDE	UG/KG	39.7	21.4	10.0		UG/KG	10.0	MAX	W<Wt;log def
CHLOROETHANE	UG/KG	39.8	21.0	3.00	J	UG/KG	3.00	MAX	W<Wt;log def

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TABLE 6-21
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
CHLOROFORM	UG/KG	39.5	22.0	4.00	J	UG/KG	4.00	MAX	W<Wt;log def
CHLOROMETHANE	UG/KG	30.0	17.8	810	J	UG/KG	17.8	95%UCL-T	W<Wt;log def
ETHYLBENZENE	UG/KG	38.6	19.1	13.0	J	UG/KG	13.0	MAX	W<Wt;log def
METHYLENE CHLORIDE	UG/KG	24.3	15.8	23.0	J	UG/KG	15.8	95%UCL-T	W<Wt;log def
TETRACHLOROETHENE	UG/KG	40.5	23.9	23.0	J	UG/KG	23.0	MAX	W<Wt;log def
TOLUENE	UG/KG	41.9	26.2	150		UG/KG	26.2	95%UCL-T	W<Wt;log def
TRANS-1,3-DICHLOROPROPENE	UG/KG	41.6	25.0	97.8	J	UG/KG	25.0	95%UCL-T	W<Wt;log def
TRICHLOROETHENE	UG/KG	39.7	22.5	12.0		UG/KG	12.0	MAX	W<Wt;log def
1,4-DICHLOROBENZENE	UG/KG	374	403	68.0	J	UG/KG	68.0	MAX	W<Wt;log def
3,3'-DICHLOROBENZIDINE	UG/KG	384	410	400		UG/KG	400	MAX	W<Wt;log def
ACENAPHTHENE	UG/KG	416	471	1,400		UG/KG	471	95%UCL-T	W<Wt;log def
ANTHRACENE	UG/KG	454	528	2,200		UG/KG	528	95%UCL-T	W<Wt;log def
BENZO(A)ANTHRACENE	UG/KG	612	882	5,200		UG/KG	882	95%UCL-T	W<Wt;log def
BENZO(A)PYRENE	UG/KG	556	810	3,800		UG/KG	810	95%UCL-T	W<Wt;log def
BENZO(B)FLUORANTHENE	UG/KG	639	941	4,900		UG/KG	941	95%UCL-T	W<Wt;log def
BENZO(G,H,I)PERYLENE	UG/KG	338	451	2,100		UG/KG	451	95%UCL-T	W<Wt;log def
BENZO(K)FLUORANTHENE	UG/KG	365	546	2,200		UG/KG	546	95%UCL-T	W<Wt;log def
BIS(2-ETHYLHEXYL)PHTHALATE	UG/KG	437	700	2,200	J	UG/KG	700	95%UCL-T	Wlg>=Wt & Wno
BUTYL BENZYL PHTHALATE	UG/KG	371	406	110	J	UG/KG	110.0	MAX	W<Wt;log def
CARBAZOLE	UG/KG	422	480	1,300		UG/KG	480	95%UCL-T	W<Wt;log def
CHRYSENE	UG/KG	597	922	4,900		UG/KG	922	95%UCL-T	W<Wt;log def
DI-N-BUTYL PHTHALATE	UG/KG	486	651	4,200		UG/KG	651	95%UCL-T	W<Wt;log def
DIBENZO(A,H)ANTHRACENE	UG/KG	380	417	450		UG/KG	417	95%UCL-T	W<Wt;log def
DIBENZOFURAN	UG/KG	383	417	570		UG/KG	417	95%UCL-T	W<Wt;log def
DIETHYL PHTHALATE	UG/KG	373	409	48.0	J	UG/KG	48.0	MAX	W<Wt;log def
FLUORANTHENE	UG/KG	1,157	1,711	13,000		UG/KG	1,711	95%UCL-T	W<Wt;log def
FLUORENE	UG/KG	419	498	1,000		UG/KG	498	95%UCL-T	W<Wt;log def
INDENO(1,2,3-CD)PYRENE	UG/KG	472	636	2,500		UG/KG	636	95%UCL-T	W<Wt;log def
NAPHTHALENE	UG/KG	372	408	250	J	UG/KG	250	MAX	W<Wt;log def
PENTACHLOROPHENOL	UG/KG	886	1,007	62.0	J	UG/KG	62.0	MAX	W<Wt;log def
PHENANTHRENE	UG/KG	844	1,181	9,900		UG/KG	1,181	95%UCL-T	W<Wt;log def
PYRENE	UG/KG	1,009	1,640	9,800		UG/KG	1,640	95%UCL-T	W<Wt;log def
ALDRIN	UG/KG	1.34	1.42	3.60		UG/KG	1.42	95%UCL-T	W<Wt;log def
ALPHA-CHLORDANE	UG/KG	1.47	1.59	5.90		UG/KG	1.59	95%UCL-T	W<Wt;log def

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TABLE 6-21
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
AROCLOR-1248	UG/KG	27.5	29.1	110	J	UG/KG	29.1	95%UCL-T	W<Wt;log def
AROCLOR-1254	UG/KG	52.2	37.5	1,150	J	UG/KG	37.5	95%UCL-T	W<Wt;log def
AROCLOR-1260	UG/KG	86.3	65.3	1,600	J	UG/KG	65.3	95%UCL-T	W<Wt;log def
DIELDRIN	UG/KG	2.69	2.87	5.80	J	UG/KG	2.87	95%UCL-T	W<Wt;log def
ENDOSULFAN II	UG/KG	2.19	2.34	8.50	J	UG/KG	2.34	95%UCL-T	W<Wt;log def
ENDOSULFAN SULFATE	UG/KG	2.73	2.90	9.30	J	UG/KG	2.90	95%UCL-T	W<Wt;log def
ENDRIN	UG/KG	3.96	4.46	20.0	J	UG/KG	4.46	95%UCL-T	W<Wt;log def
ENDRIN KETONE	UG/KG	2.60	2.75	5.50	J	UG/KG	2.75	95%UCL-T	W<Wt;log def
GAMMA-BHC (LINDANE)	UG/KG	1.32	1.39	2.50	J	UG/KG	1.39	95%UCL-T	W<Wt;log def
GAMMA-CHLORDANE	UG/KG	1.40	1.50	3.40	J	UG/KG	1.50	95%UCL-T	W<Wt;log def
HEPTACHLOR EPOXIDE	UG/KG	1.34	1.42	3.50	J	UG/KG	1.42	95%UCL-T	W<Wt;log def
HEXAVALENT CHROMIUM	UG/KG	0.0011	0.0084	0.0036	L	UG/KG	0.0036	MAX	Wlg>=Wt & Wno
4,4'-DDE	UG/KG	5.04	4.45	82.0	J	UG/KG	4.45	95%UCL-T	W<Wt;log def
4,4'-DDT	UG/KG	7.62	6.16	150	J	UG/KG	6.16	95%UCL-T	W<Wt;log def
XYLENES, TOTAL	UG/KG	39.6	20.7	38.0	J	UG/KG	20.7	95%UCL-T	W<Wt;log def
OCDD	UG/KG	0.38	1.15	0.68	J	UG/KG	0.68	MAX	Wlg>=Wt & Wno
OCDF	UG/KG	0.10	2.01	0.25	J	UG/KG	0.25	MAX	Wlg>=Wt & Wno
4,4'-DDD	UG/KG	3.93	3.92	45.0	J	UG/KG	3.92	95%UCL-T	W<Wt;log def
2-METHYLNAPHTHALENE	UG/KG	379	406	360	J	UG/KG	360	MAX	W<Wt;log def

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T) Mean of Normal Data (Mean-N).

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TABLE 6-21
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 2 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale

J - Estimated Value

4/21/00

TABLE 6-22
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ALUMINUM	MG/KG	12,725	14,010	29,500		MG/KG	14,010	95%UCL-T	Wlg>=Wt & Wno
ANTIMONY	MG/KG	5.41	9.67	16.6		MG/KG	9.67	95%UCL-T	W<Wt;log def
ARSENIC	MG/KG	5.02	6.74	17.6	J	MG/KG	6.74	95%UCL-T	Wlg>=Wt & Wno
BARIUM	MG/KG	289	419	1,530		MG/KG	419	95%UCL-T	Wlg>=Wt & Wno
BERYLLIUM	MG/KG	1.12	1.36	3.1		MG/KG	1.36	95%UCL-T	Wlg>=Wt & Wno
CADMIUM	MG/KG	7.96	32.9	67.1		MG/KG	32.9	95%UCL-T	W<Wt;log def
CALCIUM	MG/KG	10,744	22,175	42,500		MG/KG	22,175	95%UCL-T	Wlg>=Wt & Wno
CHROMIUM	MG/KG	30.8	39.7	83.4		MG/KG	39.7	95%UCL-T	W<Wt;log def
COBALT	MG/KG	10.7	12.3	23.4		MG/KG	12.3	95%UCL-T	Wlg>=Wt & Wno
COPPER	MG/KG	332	1,390	3,760		MG/KG	1,390	95%UCL-T	W<Wt;log def
IRON	MG/KG	23,293	26,714	69,500		MG/KG	26,714	95%UCL-T	Wlg>=Wt & Wno
LEAD	MG/KG	330	1,016	4,570	J	MG/KG	1,016	95%UCL-T	W<Wt;log def
MAGNESIUM	MG/KG	5,588	7,149	15,600		MG/KG	7,149	95%UCL-T	Wlg>=Wt & Wno
MANGANESE	MG/KG	733	1,073	2,330		MG/KG	1,073	95%UCL-T	Wlg>=Wt & Wno
MERCURY	MG/KG	1.26	8.20	9.7		MG/KG	8.20	95%UCL-T	W<Wt;log def
NICKEL	MG/KG	34.5	44.7	230		MG/KG	44.7	95%UCL-T	W<Wt;log def
POTASSIUM	MG/KG	1,154	1,407	3,710		MG/KG	1,407	95%UCL-T	Wlg>=Wt & Wno
SELENIUM	MG/KG	0.58	0.68	2.9		MG/KG	0.68	95%UCL-T	W<Wt;log def
SILVER	MG/KG	34.0	462	368		MG/KG	368	MAX	Max<U95log
SODIUM	MG/KG	342	486	1,460		MG/KG	486	95%UCL-T	Wlg>=Wt & Wno
THALLIUM	MG/KG	0.41	0.47	1.4	J	MG/KG	0.47	95%UCL-T	W<Wt;log def
VANADIUM	MG/KG	47.7	59.0	284		MG/KG	59.0	95%UCL-T	Wlg>=Wt & Wno
ZINC	MG/KG	725	1,970	9,100		MG/KG	1,970	95%UCL-T	W<Wt;log def
1,2-DICHLOROETHENE (TOTAL)	UG/KG	107	93.4	4	J	UG/KG	4.00	MAX	Max<U95log
2-BUTANONE	UG/KG	119	128	1,000	J	UG/KG	128	95%UCL-T	W<Wt;log def
ACETONE	UG/KG	117	223	140		UG/KG	140	MAX	Max<U95log
BENZENE	UG/KG	107	92.6	5.1	J	UG/KG	5.10	MAX	Max<U95log
CARBON DISULFIDE	UG/KG	107	102	13	J	UG/KG	13.0	MAX	Max<U95log
CHLOROBENZENE	UG/KG	112	127	140	J	UG/KG	127	95%UCL-T	W<Wt;log def
CHLOROFORM	UG/KG	107	109	1	J	UG/KG	1.00	MAX	Max<U95log
ETHYLBENZENE	UG/KG	113	141	130	J	UG/KG	130	MAX	Max<U95log
METHYLENE CHLORIDE	UG/KG	177	159	3,300		UG/KG	159	95%UCL-T	W<Wt;log def
TOLUENE	UG/KG	111	148	120		UG/KG	120	MAX	Max<U95log
1,4-DICHLOROBENZENE	UG/KG	1,519	2,502	120	J	UG/KG	120	MAX	Max<U95log

TABLE 6-22
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
ACENAPHTHENE	UG/KG	1,422	3,646	4,400	J	UG/KG	3,646	95%UCL-T	W<Wt;log def
ACENAPHTHYLENE	UG/KG	1,556	4,063	1,200		UG/KG	1,200	MAX	Max<U95log
ANTHRACENE	UG/KG	2,154	21,351	21,000		UG/KG	21,000	MAX	Max<U95log
BENZO(A)ANTHRACENE	UG/KG	3,725	37,125	53,000		UG/KG	37,125	95%UCL-T	Wlg>=Wt & Wno
BENZO(A)PYRENE	UG/KG	3,407	24,550	44,000		UG/KG	24,550	95%UCL-T	Wlg>=Wt & Wno
BENZO(B)FLUORANTHENE	UG/KG	3,578	35,976	45,000		UG/KG	35,976	95%UCL-T	Wlg>=Wt & Wno
BENZO(G,H,I)PERYLENE	UG/KG	2,251	15,030	26,000		UG/KG	15,030	95%UCL-T	W<Wt;log def
BENZO(K)FLUORANTHENE	UG/KG	2,751	32,962	34,000		UG/KG	32,962	95%UCL-T	Wlg>=Wt & Wno
BIS(2-ETHYLHEXYL)PHTHALATE	UG/KG	1,682	5,094	4,000		UG/KG	4,000	MAX	Max<U95log
BUTYL BENZYL PHTHALATE	UG/KG	1,525	2,566	41	J	UG/KG	41.0	MAX	Max<U95log
CARBAZOLE	UG/KG	1,505	2,492	1,000	J	UG/KG	1,000	MAX	Max<U95log
CHRYSENE	UG/KG	3,703	38,764	51,000		UG/KG	38,764	95%UCL-T	Wlg>=Wt & Wno
DI-N-BUTYL PHTHALATE	UG/KG	1,482	4,562	53	J	UG/KG	53.0	MAX	Max<U95log
DI-N-OCTYL PHTHALATE	UG/KG	1,539	2,254	320	J	UG/KG	320	MAX	Max<U95log
DIBENZO(A,H)ANTHRACENE	UG/KG	1,544	9,291	9,400	J	UG/KG	9,291	95%UCL-T	W<Wt;log def
DIBENZOFURAN	UG/KG	1,522	2,553	300	J	UG/KG	300	MAX	Max<U95log
DIETHYL PHTHALATE	UG/KG	1,524	2,333	86	J	UG/KG	86.0	MAX	Max<U95log
FLUORANTHENE	UG/KG	6,677	64,827	120,000		UG/KG	64,827	95%UCL-T	Wlg>=Wt & Wno
FLUORENE	UG/KG	1,405	9,115	4,500	J	UG/KG	4,500	MAX	Max<U95log
HEXACHLOROETHANE	UG/KG	1,555	2,360	640		UG/KG	640	MAX	Max<U95log
INDENO(1,2,3-CD)PYRENE	UG/KG	2,476	10,710	29,000		UG/KG	10,710	95%UCL-T	W<Wt;log def
NAPHTHALENE	UG/KG	1,560	3,875	450	J	UG/KG	450	MAX	Max<U95log
PHENANTHRENE	UG/KG	4,634	36,617	71,000		UG/KG	36,617	95%UCL-T	Wlg>=Wt & Wno
PHENOL	UG/KG	1,530	2,257	150	J	UG/KG	150	MAX	Max<U95log
PYRENE	UG/KG	5,541	36,810	97,000		UG/KG	36,810	95%UCL-T	Wlg>=Wt & Wno
ALDRIN	UG/KG	19.4	123	180	J	UG/KG	123	95%UCL-T	W<Wt;log def
AROCLOR-1242	UG/KG	46.3	58.7	84	J	UG/KG	58.7	95%UCL-T	W<Wt;log def
AROCLOR-1248	UG/KG	47.7	61.7	120		UG/KG	61.7	95%UCL-T	W<Wt;log def
AROCLOR-1254	UG/KG	381	597	5,900		UG/KG	597	95%UCL-T	W<Wt;log def
AROCLOR-1260	UG/KG	70.8	118	290	J	UG/KG	118	95%UCL-T	W<Wt;log def
ENDRIN	UG/KG	7.26	15.7	24	J	UG/KG	15.7	95%UCL-T	W<Wt;log def
GAMMA-BHC (LINDANE)	UG/KG	3.07	5.79	3.5	J	UG/KG	3.50	MAX	Max<U95log
GAMMA-CHLORDANE	UG/KG	3.98	9.68	14	J	UG/KG	9.68	95%UCL-T	W<Wt;log def
HEPTACHLOR EPOXIDE	UG/KG	3.11	5.81	6.1	J	UG/KG	5.81	95%UCL-T	W<Wt;log def

3/8/00

TABLE 6-22
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SITE 3 SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
4,4'-DDE	UG/KG	11.7	44.7	42	J	UG/KG	42.0	MAX	Max<U95log
4,4'-DDT	UG/KG	9.11	26.1	31	J	UG/KG	26.1	95%UCL-T	W<Wt;log def
XYLENES, TOTAL	UG/KG	130	220	580	J	UG/KG	220	95%UCL-T	W<Wt;log def
OCDD	UG/KG	0.95	164	2.2	J	UG/KG	2.20	MAX	Max<U95log
4,4'-DDD	UG/KG	37.9	755	150		UG/KG	150	MAX	Max<U95log
2-METHYLNAPHTHALENE	UG/KG	1,538	2,640	690		UG/KG	690	MAX	Max<U95log

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T) Mean of Normal Data (Mean-N).
J - Estimated Value

TABLE 6-23
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
1,1,2,2-TETRACHLOROETHANE	UG/KG	95	63.2	2	J	UG/KG	2	Max	Max<U95log
1,2-DICHLOROETHENE (TOTAL)	UG/KG	95.1	65.0	11	J	UG/KG	11	Max	Max<U95log
2-BUTANONE	UG/KG	87.8	59.6	23		UG/KG	23	Max	Max<U95log
4-METHYL-2-PENTANONE	UG/KG	102	73.7	450		UG/KG	73.7	95%UCL-T	W<Wt;log def
ACETONE	UG/KG	265	423	1100		UG/KG	423	95%UCL-T	W<Wt;log def
CHLOROMETHANE	UG/KG	79	55.0	2	J	UG/KG	2	Max	Max<U95log
ETHYLBENZENE	UG/KG	94.3	58.8	14	J	UG/KG	14	Max	Max<U95log
TETRACHLOROETHENE	UG/KG	94.8	60.5	10	J	UG/KG	10	Max	Max<U95log
TOLUENE	UG/KG	95.1	62.5	8	J	UG/KG	8	Max	Max<U95log
TRICHLOROETHENE	UG/KG	94.1	60.7	15	J	UG/KG	15	Max	Max<U95log
2-METHYLNAPHTHALENE	UG/KG	294	339	44	J	UG/KG	44	Max	Max<U95log
4-METHYLPHENOL	UG/KG	297	326	160	J	UG/KG	160	Max	Max<U95log
ACENAPHTHYLENE	UG/KG	285	308	560	J	UG/KG	308	95%UCL-T	W<Wt;log def
ANTHRACENE	UG/KG	283	305	510	J	UG/KG	305	95%UCL-T	W<Wt;log def
BENZO(A)ANTHRACENE	UG/KG	317	374	2700	J	UG/KG	374	95%UCL-T	W<Wt;log def
BENZO(A)PYRENE	UG/KG	341	394	3000	J	UG/KG	394	95%UCL-T	W<Wt;log def
BENZO(B)FLUORANTHENE	UG/KG	352	410	2800	J	UG/KG	410	95%UCL-T	W<Wt;log def
BENZO(G,H,I)PERYLENE	UG/KG	272	326	1700	J	UG/KG	326	95%UCL-T	W<Wt;log def
BENZO(K)FLUORANTHENE	UG/KG	250	298	1100	J	UG/KG	298	95%UCL-T	W<Wt;log def
BIS(2-ETHYLHEXYL)PHTHALATE	UG/KG	225	292	320	J	UG/KG	292	95%UCL-T	W<Wt;log def
CHRYSENE	UG/KG	357	398	3300	J	UG/KG	398	95%UCL-T	W<Wt;log def
DIBENZO(A,H)ANTHRACENE	UG/KG	306	338	34	J	UG/KG	34	Max	Max<U95log
DI-N-BUTYL PHTHALATE	UG/KG	273	314	110	J	UG/KG	110	Max	Max<U95log
FLUORANTHENE	UG/KG	396	448	3700	J	UG/KG	448	95%UCL-T	W<Wt;log def
FLUORENE	UG/KG	274	292	240	J	UG/KG	240	Max	Max<U95log
INDENO(1,2,3-CD)PYRENE	UG/KG	256	331	1300	J	UG/KG	331	95%UCL-T	W<Wt;log def
PENTACHLOROPHENOL	UG/KG	697	789	120	J	UG/KG	120	Max	Max<U95log
PHENANTHRENE	UG/KG	277	322	1900	J	UG/KG	322	95%UCL-T	W<Wt;log def
PYRENE	UG/KG	532	545	7000		UG/KG	545	95%UCL-T	W<Wt;log def
4,4'-DDD	UG/KG	13.1	20.8	150		UG/KG	20.8	95%UCL-T	W<Wt;log def
4,4'-DDE	UG/KG	2.8	3.54	3.7	J	UG/KG	3.54	95%UCL-T	W<Wt;log def
4,4'-DDT	UG/KG	6.8	7.67	78		UG/KG	7.67	95%UCL-T	W<Wt;log def
ALDRIN	UG/KG	1.54	1.68	2.3	J	UG/KG	1.68	95%UCL-T	W<Wt;log def
ALPHA-CHLORDANE	UG/KG	1.47	1.66	0.25	J	UG/KG	0.25	Max	Max<U95log

TABLE 6-23
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
AROCLOR-1242	UG/KG	29.3	31.7	31	J	UG/KG	31	Max	Max<U95log
AROCLOR-1254	UG/KG	30.6	33.8	44		UG/KG	33.8	95%UCL-T	W<Wt;log def
AROCLOR-1260	UG/KG	60.4	55.2	930		UG/KG	55.2	95%UCL-T	W<Wt;log def
DELTA-BHC	UG/KG	1.6	2.17	9.9	J	UG/KG	2.17	95%UCL-T	W<Wt;log def
DIELDRIN	UG/KG	2.57	5.54	21		UG/KG	5.54	95%UCL-T	W<Wt;log def
ENDOSULFAN I	UG/KG	1.45	1.85	0.8	J	UG/KG	0.8	Max	Max<U95log
ENDOSULFAN II	UG/KG	3.13	4.5	19	J	UG/KG	4.5	95%UCL-T	W<Wt;log def
ENDRIN	UG/KG	2.6	4.12	13	J	UG/KG	4.12	95%UCL-T	W<Wt;log def
ENDRIN ALDEHYDE	UG/KG	2.84	3.15	0.63	J	UG/KG	0.63	Max	Max<U95log
ENDRIN KETONE	UG/KG	2.49	3.65	13	J	UG/KG	3.65	95%UCL-T	W<Wt;log def
GAMMA-BHC (LINDANE)	UG/KG	1.41	1.87	0.19	J	UG/KG	0.19	Max	Max<U95log
GAMMA-CHLORDANE	UG/KG	1.6	2.08	13	J	UG/KG	2.08	95%UCL-T	W<Wt;log def
HEPTACHLOR	UG/KG	1.47	1.91	1.2	J	UG/KG	1.2	Max	Max<U95log
HEPTACHLOR EPOXIDE	UG/KG	1.43	2	0.059	J	UG/KG	0.059	Max	Max<U95log
METHOXYCHLOR	UG/KG	13.62	33	0.81	J	UG/KG	0.81	Max	Max<U95log
ALUMINUM	MG/KG	11,340	12,361	20100		MG/KG	12,361	95%UCL-T	W<Wt;log def
ANTIMONY	MG/KG	10.2	21.1	144	J	MG/KG	21.1	95%UCL-T	W<Wt;log def
ARSENIC	MG/KG	1.76	2.33	6.4		MG/KG	2.33	95%UCL-T	Wlg>=Wt & Wno
BARIUM	MG/KG	101	111	316		MG/KG	111	95%UCL-T	W<Wt;log def
BERYLLIUM	MG/KG	1.04	1.16	6.7		MG/KG	1.16	95%UCL-T	W<Wt;log def
CADMIUM	MG/KG	4.45	3.56	91.1		MG/KG	3.56	95%UCL-T	W<Wt;log def
CALCIUM	MG/KG	6,994	6,068	132000		MG/KG	6,068	95%UCL-T	W<Wt;log def
CHROMIUM	MG/KG	252	244	4730		MG/KG	244	95%UCL-T	W<Wt;log def
COBALT	MG/KG	14.8	16.4	61.4		MG/KG	16.4	95%UCL-T	W<Wt;log def
COPPER	MG/KG	27.3	34.7	707	J	MG/KG	34.7	95%UCL-T	W<Wt;log def
CYANIDE	MG/KG	4.67	5.49	79.6		MG/KG	5.49	95%UCL-T	W<Wt;log def
HEXAVALENT CHROMIUM	MG/KG	1.61	16.3	22.5	J	MG/KG	16.3	95%UCL-T	W<Wt;log def
IRON	MG/KG	19,846	23,272	91700		MG/KG	23,272	95%UCL-T	Wlg>=Wt & Wno
LEAD	MG/KG	14.1	19.2	89.8		MG/KG	19.2	95%UCL-T	W<Wt;log def
MAGNESIUM	MG/KG	3,767	4,271	42800		MG/KG	4,271	95%UCL-T	W<Wt;log def
MANGANESE	MG/KG	1,077	1,355	6090		MG/KG	1,355	95%UCL-T	W<Wt;log def
MERCURY	MG/KG	0.14	0.11	2.6		MG/KG	0.11	95%UCL-T	W<Wt;log def
NICKEL	MG/KG	17.7	19.7	62.7		MG/KG	19.7	95%UCL-T	W<Wt;log def
POTASSIUM	MG/KG	1,518	2,030	5680		MG/KG	2,030	95%UCL-T	W<Wt;log def

TABLE 6-23
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION IMPOUNDMENT AREA SUBSURFACE SOIL (POST-REMOVAL)
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact (Ing. & Der.) with Subsurface Soil, Industrial Adult*

Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL of Normal Data (1)	Maximum Detected Concentration	Maximum Qualifier	EPC Units	Reasonable Maximum Exposure		
							Medium EPC Value	Medium EPC Statistic	Medium EPC Rationale
SILVER	MG/KG	11.4	7.2	373	J	MG/KG	7.2	95%UCL-T	W<Wt;log def
SODIUM	MG/KG	116.8	127.4	612		MG/KG	127.4	95%UCL-T	W<Wt;log def
THALLIUM	MG/KG	0.47	0.49	1.1	J	MG/KG	0.49	95%UCL-T	W<Wt;log def
VANADIUM	MG/KG	17.9	19.9	33.7		MG/KG	19.9	95%UCL-T	W<Wt;log def
ZINC	MG/KG	44.2	52.2	327	J	MG/KG	52.2	95%UCL-T	W<Wt;log def

*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Industrial Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Child (Age 1-6).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Pre-Adolescent/Adolescent (Age 7-16).
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Casual User Adult.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Child.
*This screening is also valid for Current/Future/Surface Soil/Surface Soil/Contact (Ing. & Der.) with Surface Soil Residential Adult.
*This screening is also valid for Current/Future/Surface Soil/ Particulates/Contact (Inhalation) with Surface Soil Residential Adult.

(1) Represents the 95% UCL of normal data for normal distributions; Represents the log-transformed 95% UCL for lognormal distributions.
Statistics: Maximum Detected Value (Max); 95% UCL of Normal Data (95%UCL-N); 95% UCL of Log-transformed Data (95%UCL-T); Mean of Log-Transformed Data (Mean-T) Mean of Normal Data (Mean-N).
J - Estimated Value

risk associated with exposure to an individual COPC was then estimated by multiplying the risk at the RBC by a simple ratio involving the appropriate RBC and the RME EPC. Finally, COPC-specific risks were summed to determine whether the estimated cumulative cancer risk for the assessed exposure route exceeds the benchmark of 5×10^{-5}.

Typically, action is initiated at a site when the cumulative cancer risk for all pathways and routes of exposure surpasses 1×10^{-4}. For screening purposes, a benchmark of 5×10^{-5} was instituted to account for potential risks posed by pathways and routes not considered by the described process. As a preliminary assessment, the risk-ratio comparison is regarded as a reasonable approach for determining the need for a more detailed and site-specific evaluation.

6.3.2 Non-Cancer Effects

As with the carcinogens, the maximum detected concentrations of each non-cancer COPC was compared to the appropriate RBC. The potential risk associated with exposure to an individual COPC was then estimated by multiplying the hazard index at the RBC by a simple ratio involving the respective RBC. COPC-specific risks were then summed to determine whether the estimated cumulative non-cancer risk for the assessed exposure route exceeds the established benchmark of 0.5.

Typically, action is initiated at a site when the cumulative non-cancer risk for all pathways and routes of exposure surpasses the benchmark of 1.0. For screening purposes, a benchmark of 0.5 was instituted to account for potential risks posed by pathways and routes not considered by the described process. As a preliminary assessment, the risk-ratio comparison is regarded as a reasonable approach for determining the need for a more detailed and site-specific evaluation.

If the non-cancer and cancer benchmarks are not exceeded, no additional human health risk assessment would be required. If either of the risk-ratio screening levels ($5x\ 10^{-5}$ for excess lifetime cancer risk and/or 0.5 for non-cancer hazard) is exceeded, a site-specific quantitative assessment of risk will be estimated considering all pathways and routes of exposure

6.3.3 Risk Ratio Comparison Results

The future anticipated land use at Area A is expected to be light industrial/commercial. Likely potential receptors include light industrial workers and office workers from surrounding neighborhoods. Residential land use is not anticipated for this site. Risks estimated assuming residential land use provide a baseline to which all receptor risks can be compared; however, residential risks are purely hypothetical in nature. If the land use designation were to change in the future, quantitative risks estimated in this section should be re-evaluated.

Risk ratio comparisons were determined for surface and subsurface soils separately for chemicals identified as COPCs by screening against both residential and industrial RBCs. The results of the risk ratio comparison are shown in Tables 6-4 and 6-5 for surface soil and Tables 6-10 and 6-11 for subsurface soil.

6.3.3.1 Site 1 Soils

There were no COPCs in surface soil at Site 1; therefore, the risk ratio analysis was not performed for this site or medium. No carcinogenic COPCs were selected for Site 1 subsurface soil. Consequently, there is no need for a toxicological evaluation for the carcinogenic COPCs. However, based on industrial/commercial COPCs, the noncancer hazard risk ratio sum was 0.75 for subsurface soil, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

Based on residential COPCs, the noncancer hazard risk ratio sum for Site 1 subsurface soil was 24.66, indicating that a toxicological evaluation is also necessary for noncarcinogenic COPCs.

6.3.3.2 Site 2 Soils

Based on industrial/commercial COPCs, the total carcinogenic risk ratio sum for Site 2 surface soil was 7.37×10^{-6}, below the risk ratio cutoff of 5×10^{-5}. Consequently, there is no need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 1.39, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

The total carcinogenic risk ratio sum for Site 2 surface soil, based on residential COPCs, was 6.59×10^{-5}, above the risk ratio cutoff of 5×10^{-5}. Consequently, there is a need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 13.97, indicating that a toxicological evaluation is also necessary for noncarcinogenic COPCs.

The total carcinogenic risk ratio sum for Site 2 subsurface soil, based on industrial/commercial COPCs, was 5.80×10^{-6}, below the risk ratio cutoff of 5×10^{-5}. Consequently, there is no need for a toxicological evaluation for the carcinogenic COPCs. However, the noncancer hazard risk ratio sum was 6.02, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

Based on residential COPCs, the total carcinogenic risk ratio sum for Site 2 subsurface soil was 1.18×10^{-4}, above the risk ratio cutoff of 5×10^{-5}. Consequently, there is a need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 84.45, indicating that a toxicological evaluation is also necessary for noncarcinogenic COPCs.

6.3.3.3 Site 3 Soils

The total carcinogenic risk ratio sum for Site 3 surface soil, based on industrial/commercial COPCs, was 1.79×10^{-6}, below the risk ratio cutoff of 5×10^{-5}. Consequently, there is no need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 0 (no noncarcinogenic COPCs), indicating that a toxicological evaluation is also not necessary for noncarcinogenic COPCs.

Based on residential COPCs, the total carcinogenic risk ratio sum for Site 3 surface soil was 2×10^{-5}, below the risk ratio cutoff of 5×10^{-5}. Consequently, there is a no need for a toxicological evaluation for the carcinogenic COPCs. However, the noncancer hazard risk ratio sum was 1.11, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

The total carcinogenic risk ratio sum for Site 3 subsurface soil, based on industrial/commercial COPCs, was 9.10×10^{-5}, above the risk ratio cutoff of 5×10^{-5}. Consequently, there is a need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 6.67, indicating that a toxicological evaluation is also necessary for noncarcinogenic COPCs.

Based on residential COPCs, the total carcinogenic risk ratio sum for Site 3 subsurface soil was 8.24×10^{-4}, above the risk ratio cutoff of 5×10^{-5}. Consequently, there is a need for a toxicological evaluation for the carcinogenic COPCs. Further, the noncancer hazard risk ratio sum was 72.32, indicating that a toxicological evaluation is also necessary for noncarcinogenic COPCs

6.3.3.4 Impoundment Area Subsurface Soil

There was no surface soil sampling at the Impoundment Area, thus, only subsurface soil is evaluated. Based on industrial/commercial COPCs, the total carcinogenic risk ratio sum for the impoundment area subsurface soil was 3.83×10^{-6}, below the risk ratio cutoff of 5×10^{-5}. Consequently, there is no need for a toxicological evaluation for the carcinogenic COPCs. However, the non-cancer hazard risk ratio sum was 1.10, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

The total carcinogenic risk ratio sum for the Impoundment Area subsurface soil, based on residential COPCs, was 4.5×10^{-5}, and below the risk ratio cutoff of 5×10^{-5}. Because the sum was close to the cutoff, a toxicological evaluation for the carcinogenic COPCs was performed. Further, the noncancer hazard risk ratio sum was 34.24, indicating that a toxicological evaluation is necessary for noncarcinogenic COPCs.

6.4 TOXICOLOGICAL EVALUATION AND RISK CHARACTERIZATION

A toxicological evaluation and more quantitative risk characterization were conducted to evaluate potential cancer and non-cancer health risks from ingestion of soil for COPCs exceeding risk ratio benchmarks. Cancer slope factors (CSFs) and reference doses (RfDs) for each COPC used in this toxicological evaluation are presented in Tables 6-24 and 6-25.

If the toxicological evaluation indicates that there are no excess lifetime cancer and/or non-cancer risks to the maximally exposed populations, then no corrective action would be required to be protective of human health. If the toxicological evaluation indicates that there are excess lifetime cancer or non-cancer risks to the maximally exposed populations, then further site assessment may be necessary. The following risk management options may be considered: (1) additional sampling and reassessment of human health risks by conducting a toxicological evaluation on the expanded data set; (2) hot spot identification and remediation and confirmation sampling and assessment; and/or (3) additional sampling (if necessary) and performance of a complete CERCLA risk assessment.

For the purpose of this toxicological evaluation, an industrial/commercial adult worker was chosen as the maximally exposed human receptor population. Residential reuse of Area A is not planned; however, risks were evaluated for the future hypothetical residential child for informational purposes only. For purposes of this risk assessment, the residential child exposure scenario represents the relative worst-case scenario. The construction worker scenario was not considered in this evaluation because under standard default exposure assumptions, the industrial/commercial worker is considered to be at approximately four-fold risk over that of the construction worker. Therefore, if there are no risks to the industrial/commercial worker, it can be assumed that there would be no risks to the construction worker. Figure 6-1 displays the conceptual site model for human health risks related to Area A.

Potential human health risks resulting from the exposures outlined in the preceding sections are characterized on a quantitative and qualitative basis in this section. Quantitative risk estimates were generated based on risk assessment methods outlined in current EPA guidance (EPA, 1989a).

Noncarcinogenic risk estimates were presented in the form of Hazard Quotients (HQs) and Hazard Indices (HIs) that are determined through comparison of estimated intakes with published RfDs. Incremental cancer risk estimates were provided in the form of dimensionless probabilities based on slope factors (SFs).

TABLE 6-24

CANCER TOXICITY DATA -- ORAL

NAWC WARMINSTER, PENNSYLVANIA

Chemical of Potential Concern	Oral Cancer Slope Factor	Units	Weight of Evidence/ Cancer Guideline Description	Source Target Organ	Date (2) (MM/DD/YY)
ALDRIN	1.70E+01	mg/kg	B2	IRIS	10/01/99
AROCLOR-1254	2.00E+00	mg/kg	B2	IRIS	10/01/99
AROCLOR-1260	2.00E+00	mg/kg	B2	IRIS	10/01/99
ARSENIC	1.50E+00	mg/kg	A-inhalation	IRIS	10/01/99
BENZ[A]ANTHRACENE	7.30E-01	mg/kg	B2	IRIS	10/01/99
BENZO[A]PYRENE	7.30E+00	mg/kg	B2	IRIS	10/01/99
BENZO[B]FLUORANTHENE	7.30E-01	mg/kg	B2	IRIS	10/01/99
DIBENZ[A,H]ANTHRACENE	7.30E+00	mg/kg	B2	IRIS	10/01/99
INDENO[1,2,3-C,D]PYRENE	7.30E-01	mg/kg	B2	IRIS	10/01/99

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

(1) Provide equation for derivation in text.

(2) For IRIS values, provide the date IRIS was searched.

For HEAST values, provide the date of HEAST.

For NCEA values, provide the date of article provided by NCEA.

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TABLE 6-25

NON-CANCER TOXICITY DATA -- ORAL

NAWC WARMINSTER, PENNSYLVANIA

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (3) (MM/DD/YY)
ALDRIN	Chronic	3.00E-05	mg/kg-day	mg/kg	Liver	100	IRIS	10/1/99
ALUMINUM	Chronic	1.00E+00	mg/kg-day	mg/kg	CNS		IRIS	10/1/99
ANTIMONY	Chronic	4.00E-04	mg/kg-day	mg/kg	Longevity/Blood	1,000	IRIS	10/1/99
ARSENIC	Chronic	3.00E-04	mg/kg-day	mg/kg	Skin	3	IRIS	10/1/99
BARIUM	Chronic	7.00E-04	mg/kg-day	mg/kg	Blood Pressure	1,000	IRIS	10/1/99
CADMIUM	Chronic	5.00E-04	mg/kg-day	mg/kg	Kidney	10	IRIS	10/1/99
CHROMIUM VI	Chronic	3.00E-04	mg/kg-day	mg/kg	NOAEL	1,000	IRIS	10/1/99
COPPER	Chronic	4.00E-02	mg/kg-day	mg/kg				
MANGANESE	Chronic	7.00E-02	mg/kg-day	mg/kg	CNS		IRIS	10/1/99
MERCURY	Chronic	3.00E-04	mg/kg-day	mg/kg	Autoimmune System	1,000	IRIS	10/1/99
NICKEL	Chronic	2.00E-02	mg/kg-day	mg/kg	Decreased Body/Organ	300	IRIS	10/1/99
SILVER	Chronic	5.00E-03	mg/kg-day	mg/kg	Argyria	3E+00	IRIS	10/1/99
THALLIUM	Chronic	7.00E-05	mg/kg-day	mg/kg				
VANADIUM	Chronic	7.00E-03	mg/kg-day	mg/kg	Lifetime	1E+02	IRIS	10/1/99
ZINC	Chronic	3.00E-01	mg/kg-day	mg/kg	Blood Pressure	3	IRIS	10/1/99

N/A = Not Applicable

(1) Refer to RAGS, Part A

(2) Provide equation used for derivation.

(3) For IRIS values, provide the date IRIS was searched.

For HEAST values, provide the date of HEAST.

For NCEA values, provide the date of the article provided by NCEA.

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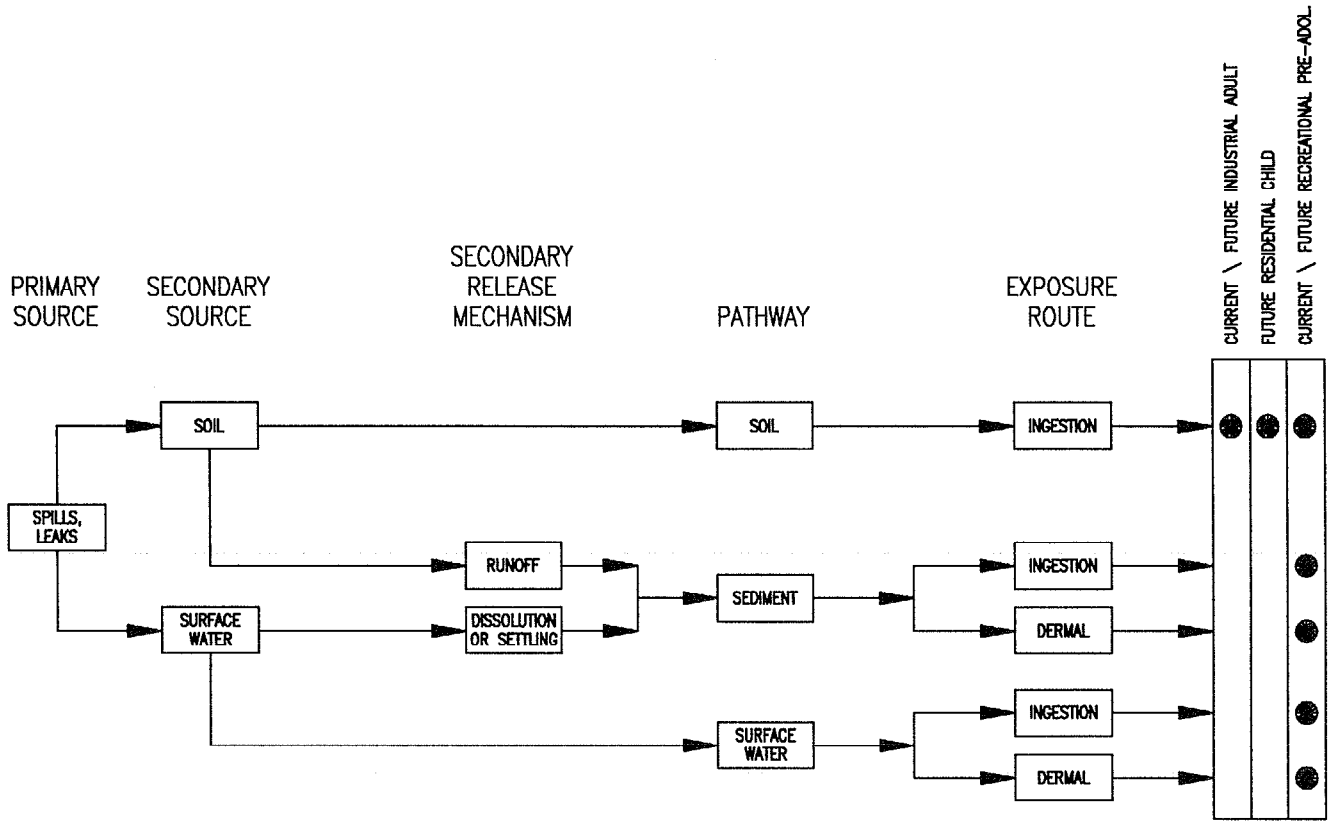

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Tetra Tech NUS, Inc.

AREA A, POST EXCAVATION
CONCEPTUAL MODE
HUMAN HEALTH RISK ASSESSMENT
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 1412
OWNER NO. 4010
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Estimated human intakes were developed for the ingestion route of exposure as discussed in Section 6.4.5.1. Both noncarcinogenic and carcinogenic risks were summarized for all COPCs in a series of tables in this section.

6.4.1 Noncarcinogenic Risks

Noncarcinogenic risk was assessed using the concept of HQs and HIs. The HQ is defined as the ratio of the estimated intake and the RfD for a selected chemical of concern, as follows:

$$HQ = \frac{Intake}{RfD}$$

HIs were generated by summing the individual HQs for the COPCs. If the value of the HI exceeds unity (1.0), the potential for noncarcinogenic health risks associated with exposure to that particular chemical mixture cannot be ruled out (EPA, 1986b). In that case, particular attention should be paid to the target organ(s) affected by each chemical because these are generally the organ(s) associated with RfD-derived effects, and results (HIs) for different organs are not truly additive. The HI is not defined as a mathematical prediction of the severity of toxic effects; it is simply a numerical indicator of the possibility of the occurrence of noncarcinogenic (threshold) effects.

6.4.2 Carcinogenic Risks

Incremental cancer risk estimates were generated for each of the exposure pathways using the estimated intakes and published SFs, as follows:

$$Risk = Intake * SF$$

If the above equation results in a risk greater than 0.01, the following equation was used:

$$Risk = 1 - e^{-(Intake*SF)}$$

The risk determined using these equations is defined as a unitless expression of an individual's increased likelihood of developing cancer as a result of exposure to carcinogenic chemicals. An incremental cancer risk of 1×10^{-6} indicates that the exposed receptor has a one in a million chance of developing cancer under the defined exposure scenario. Alternatively, such a risk may be interpreted as representing one additional case of cancer in an exposed population of one million persons. The calculated cancer risks should be recognized as upper-limit estimates. SFs are defined as the upper 95 percent confidence limit

of a dose-response curve generally derived from animal studies. Actual human risk, while not identifiable, is not expected to exceed the upper limit based on the SFs and may, in fact, be lower.

EPA has generally defined risks in the range of 10^{-4} to 10^{-6} as being acceptable for most hazardous waste facilities addressed under CERCLA. For CERCLA activities, residual risks on the order of 10^{-6} are the primary goal but are often modified by such regulatory requirements as MCLs or chemical-specific clean-up goals.

6.4.3 Comparison of Quantitative Risk Estimates to Benchmark Criteria

In order to interpret the quantitative risks and to aid risk managers in determining the need for remediation at a site, quantitative risk estimates are compared to typical benchmarks.

An HI exceeding unity (1.0) indicates that there may be potential noncarcinogenic health risks associated with exposure. If an HI exceeds unity, target organ effects from individual COPCs contributing to the risk are considered. Only those chemicals that impact the same target organ(s) or exhibit similar critical effect(s) will be regarded as truly additive. Thus, COPCs contributing to an HI greater than 1.0 on the basis of a single target organ/effect are considered to be COCs.

EPA has defined the range of 10^{-4} to 10^{-6} as the incremental cancer risk (ICR) "target range" for most hazardous waste facilities evaluated. Cumulative ICRs greater than 10^{-4} generally will indicate that some degree of remediation is required, and ICRs below 10^{-6} normally will not result in remedial efforts. Whenever ICRs fall between 10^{-4} to 10^{-6}, decisions for remediation will be made on a case-specific basis. Individual chemicals contributing significantly to risks above the target range are considered to be chemicals of concern (COCs).

Potential RME hazard indices and RME cancer risks were estimated for current and future potential receptors using the methodologies presented in Sections 6.2 through 6.4. The following sections present a summary of the results of the estimation of risk at Area A.

Receptor risks are presented for each area of interest in the form of tables and summary text. Each of these sections includes summaries of risks estimated by the exposure scenarios. It should be noted that, in each risk summary table where HQs are reported as "N/A," the HQs were not calculable because no RfD has been established. Usually in such cases, carcinogenicity is considered to be more important, since carcinogenicity will generally be seen at lower doses than noncarcinogenic effects. Cancer risks that are reported as "N/A" generally indicate that the chemical is not carcinogenic or that an SF has not yet been developed.

6.4.4 Potential Receptors

The potential receptors chosen for Area A are discussed in detail in this section. The on-/off-base receptors were selected based on several criteria (i.e., current and anticipated future land use, accessibility to the site, and media of interest sampled) and are listed as follows:

6.4.4.1 Surface and Subsurface Soil Exposure

The surface and subsurface soil exposure scenarios are presented below:

- Current/Future Industrial/Commercial Adult - This receptor is an adult who uses Area A for work-related industrial purposes 250 days/year. This receptor is potentially exposed via ingestion of COPCs in surface and subsurface soils.
- Future Residential Child - This receptor is a child (age 0 to 6) who resides at or near Area A for 350 days per year. This receptor is potentially exposed via ingestion of COPCs in surface and subsurface soils.

6.4.4.2 Surface Water Exposure

Two potential exposure routes were associated with direct exposure to off-base Area A surface water: incidental ingestion and dermal contact. Surface water samples collected in Area A were evaluated using recreational child receptors. The surface water adjacent to Area A is reported to be not large enough to support food fish or swimming; therefore, only a wading scenario was evaluated. It was assumed that the recreational children in this wading scenario would be older than the standard 15-kilogram child (approximately age three) used in standard residential child scenarios. For surface water exposure, a 25-kilogram child (approximately 6 years old) was used. Therefore, the selected receptors were 25-kilogram recreational children and the exposure pathways were incidental ingestion and dermal contact with surface water. Inhalation of chemicals in surface water vapors was eliminated as a pathway because volatilization is not expected to be significant. Furthermore, the frequency of contact with surface water by recreational children is expected to be low since the nearby stream north of Area A lies on a private property, which is used for commercial land use.

6.4.4.3 Sediment Exposure

The exposure routes for sediment were the same as for Area A surface water. Two potential exposure routes (ingestion and dermal absorption) were associated with direct exposure to sediment at off-base areas adjacent to Area A. For sediment, both exposure routes were evaluated using the

current/futurerecreational pre-adolescent (age 7 to 12) receptor. This receptor was chosen because it is expected to be representative of typical recreational exposures at off-base areas.

6.4.5 Exposure Estimates

The exposure routes, methods, and models presented in this section are consistent with current EPA risk assessment guidance (EPA, 1989a, 1991c, 1996b, and 1998b). Exposure estimates associated with each exposure route are presented below. All exposure scenarios incorporate RME EPCs in the estimation of intakes. There are four environmental media for Area A through which potential receptors (see previous section) can be either directly or indirectly exposed to site-related COPCs: surface soil, subsurface soil, off-base sediment, and off-base surface water.

Exposure doses for the evaluation of noncarcinogenic risks were estimated using the concept of an average annual exposure. The intake incorporates terms describing the exposure time and/or frequency that represent the number of hours per day and the number of days per year that exposure occurs. This is used along with the "averaging time," which converts the daily exposure frequency and duration to an annual exposure by dividing by 365 days per year of exposure. Noncarcinogenic risks for some exposure routes (e.g., soil) are generally greater for children than for adults because of differences in body weight and intake. Carcinogenic risks, on the other hand, were calculated as an incremental lifetime risk and, therefore, the exposure dose for the evaluation of cancer risk incorporates terms to represent the exposure duration (years) over the course of a lifetime (70 years).

6.4.5.1 Surface and Subsurface Soil Exposure Estimates

Only the ingestion exposure pathway was considered for this toxicological evaluation. Although there are three potential exposure routes that may be associated with direct exposure to surface and subsurface soil at Area A, the dermal and inhalation pathways are not expected to significantly increase the calculated risks through the ingestion pathway and are therefore not calculated in this evaluation. Because of low permeability rates of substances through the skin, the dermal pathway for soils typically contributes less than 20% of the total risk. The inhalation pathway for soils typically contributes two to four orders of magnitude lower risk than the ingestion pathway.

For surface and subsurface soils, the ingestion exposure route was evaluated using the current/future industrial/commercial adult receptor and hypothetical future residential child receptor. These receptors were chosen to provide reasonable assessments of industrial/commercial or hypothetical residential exposure scenarios at Area A.

Table 6-26 presents the RME input parameters selected for the surface and subsurface exposure pathways for the current/future industrial/commercial adult. Table 6-27 presents the RME input

TABLE 6-26

VALUES USED FOR DAILY INTAKE CALCULATIONS (POST-REMOVAL)

NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Surface and Subsurface
Exposure Point: Sites 1, 2, 3 & Impoundment area
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	Intake Equation/ Model Name
Ingestion	ADI	Average Daily Intake	mg/kg/day			
	CS	Soil Concentration	mg/kg	chem-specific		ADI = (CS x IR x FI x EF x ED) / (BW x AT)
	IR	Ingestion Rate	mg soil/day	50	USEPA 1991	
	FI	Fraction Ingested	unitless	1	USEPA 1991	
	EF	Exposure Frequency	days/year	250	USEPA 1991	
	ED	Exposure Duration	years	25	USEPA 1991	
	BW	Body Weight	kg	70	USEPA 1991	
	ATcancer	Averaging Time - cancer	days	25,550	USEPA 1991	
	ATnoncancer	Averaging Time - noncancer	days	9,125	USEPA 1991	

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TABLE 6-27

VALUES USED FOR DAILY INTAKE CALCULATIONS (POST-REMOVAL)

NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future (Hypothetical)
Medium: Soil
Exposure Medium: Surface and Subsurface
Exposure Point: Sites 1, 2, 3 & Impoundment area
Receptor Population: Residential
Receptor Age: Child (0-6 years)

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	Intake Equation/ Model Name
Ingestion	ADI	Average Daily Intake	mg/kg/day			
	CS	Soil Concentration	mg/kg	chem-specific		ADI = (CS x IR x FI x EF x ED) / (BW x AT)
	IR	Ingestion Rate	mg soil/day	200	USEPA 1991	
	FI	Fraction Ingested	unitless	1	USEPA 1991	
	EF	Exposure Frequency	days/year	350	USEPA 1991	
	ED	Exposure Duration	years	6	USEPA 1991	
	BW	Body Weight	kg	15	USEPA 1991	
	ATcancer	Averaging Time - cancer	days	25,550	USEPA 1991	
	ATnoncancer	Averaging Time - noncancer	days	2,190	USEPA 1991	

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parameters selected for the surface and subsurface exposure pathways for the hypothetical future residential child. The rationale for each exposure surface and subsurface soil input parameter is presented in these tables.

6.4.5.2 Sediment Exposure Estimates

Tables 6-28 (ingestion) and 6-29 (dermal contact) present the RME input parameters (and rationale) selected for the sediment exposure pathways for the current/future recreational pre-adolescent. A soil-to-skin adherence factor of 0.2 mg/cm^2/event was used for sediment, since the nearby stream is often void of water and more closely resembles dry soil. The only input values not shown on the exposure input tables are the chemical specific absorption factors for the dermal pathway. These values are provided by EPA Region III. For sediment COPCs, absorption factors are as follows (EPA, 1995a): arsenic (3%), iron (1%), and manganese (1%). Note: EPA (1989a) states that it is inappropriate to estimate the risks associated with dermal exposure to PAHs, which cause cancer through a direct action at the point of application. Deviation of the surface areas (used in all dermal exposure equations in this risk assessment) for the potential receptor was based upon the sum of the values for contributing body parts.

6.4.5.3 Surface Water Exposure Estimates

Tables 6-30 (ingestion) and 6-31 (dermal contact) present the RME input parameters (and rationale) selected for the surface water exposure pathways for the current/future recreational pre-adolescent. The only input values not shown on the exposure input tables are the chemical specific permeability constants for the dermal pathway. Derivation of the surface areas (used in all dermal exposure equations in this risk assessment) for the potential receptor was based upon the sum of the values for contributing body parts.

6.4.6 Site-Specific Noncarcinogenic Risks for Soils

Noncarcinogenic risks estimated for potential receptors are discussed below and presented in the appropriate tables. For purposes of this assessment, risks were not examined by target organs as many of the calculated hazards for individual COPC concentrations were above unity (i.e., 1.0).

6.4.6.1 Site 1 Soils

The estimated RME hazard indices for an industrial/commercial adult or for a future hypothetical residential child exposed to surface soil at Site 1 were not calculated because no COPCs failed screening criteria.

TABLE 6-28
EXPOSURE INPUT PARAMETERS - SEDIMENT INGESTION
NAWC WARMINSTER, PENNSYLVANIA

Incidental Ingestion of Sediment			
Input Parameter	Description	Value	Rationale
C	Exposure concentration	Representative concentration (mg/kg)	Upper 95% confidence limit on arithmetic average (based upon normal or log-transformed data distribution) (EPA, 1989a)
IR	Ingestion rate	200 mg/day (recreational child)	(EPA, 1991a)
FI	Fraction ingested from contaminated source	1.0	Professional judgement based on current and projected future land use and observed activity patterns
EF	Exposure frequency	7 days/year (recreational child)	(EPA, 1991a)
ED	Exposure duration	6 years (recreational child)	(EPA, 1991a)
BW	Body weight	25 kg (recreational child)	Wading is expected to occur for older children (age 6 and older; weight 25 kg (EPA, 1991a)
AT	Averaging time	ED x 365 days/year	Noncarcinogens (EPA, 1989a)
		70 years x 365 days/year	Carcinogens (EPA, 1989a)

TABLE 6-29
EXPOSURE INPUT PARAMETERS - DERMAL CONTACT WITH SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

Dermal Contact with Sediment			
Input Parameter	Description	Value	Rationale
C	Exposure concentration	Representative concentration (mg/kg)	Upper 95% confidence limit on arithmetic average (based upon normal or log-transformed data distribution) (EPA, 1989a
SA	Skin surface area available for contact	792 sq. cm/day	Feet only; child; sediment (EPA, 1991g)
AF	Soil-to-skin adherence facto	0.2 mg/sq. cm	(EPA, 1992f)
ABS	Absorption factor	Inorganics = 0.01 (except arsenic) SVOCs/Pest = 0.1 PCBs = 0.06 VOCs = if VP>benzene, 0.0005 if VP<benzene, 0.03 Arsenic = 0.03	Feldman and Maibach (1970) Webster and Maibach (1985) EPA (1984a) EPA (1995)
EF	Exposure frequency	7 days/year (recreational child)	(EPA, 1991a)
ED	Exposure duration	6 years (recreational child)	(EPA, 1991a)
BW	Body weight	25 kg (recreational child)	Wading is expected to occur for older children (age 6 and older; weight 25 kg) (EPA, 1991a)
AT	Averaging time	ED x 365 days/year	Noncarcinogens (EPA, 1989a)
		70 years x 365 days/year	Carcinogens (EPA, 1989a)

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TABLE 6-30
EXPOSURE INPUT PARAMETERS - SURFACE WATER INGESTION
NAWC WARMINSTER, PENNSYLVANIA

Incidental Ingestion of Surface Water (Recreational Children)			
Input Parameter	Description	Value	Rationale
C	Exposure concentration	Representative concentratio (mg/L)	Upper 95% confidence limit on arithmetic average (based upon normal or log-transformed data distribution) (EPA, 1989a)
IR	Ingestion rate	0.2 L/day	(EPA, 1989a)
EF	Exposure frequency	7 days/year	(EPA, 1989a)
ED	Exposure duration	6 years	(EPA, 1991a)
BW	Body weight	25 kg (recreational child)	Wading is expected to occur for older children (age 6 and older; weight 25 kg) (EPA, 1991a)
AT	Averaging time	ED x 365 days/year	Noncarcinogens (EPA, 1989a)
		70 years x 365 days/year	Carcinogens (EPA, 1989a)

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TABLE 6-31
EXPOSURE INPUT PARAMETERS - DERMAL CONTACT WITH SURFACE WATER
NAWC WARMINSTER, PENNSYLVANIA

Dermal Contact with Surface Water			
Input Parameter	Description	Value	Rationale
C	Exposure concentration	Representative concentration (mg/L)	Upper 95% confidence limit on arithmetic average (based upon normal or log-transformed data distribution) (EPA, 1989a)
SA	Skin surface area available for contact	3,580 sq. cm/day	Wading: legs, feet, and hands (EPA, 1989b)
ET	Exposure time	2.6 hours/day	(EPA, 1989a)
EF	Exposure frequency	7 days/year	(EPA, 1989a)
ED	Exposure duration	6 years	(EPA, 1991a)
BW	Body weight	25 kg (recreational child)	Wading is expected to occur for older children (age 6 and older; weight 25 kg) (EPA, 1991a)
AT	Averaging time	ED x 365 days/year	Noncarcinogens (EPA, 1989a)
		70 years x 365 days/year	Carcinogens (EPA, 1989a)
K, Kp	Permeability coefficients (cm/hour)	Contaminant-specific	(EPA, 1992f)
TAU	Lagtime (hours)	Contaminant-specific	(EPA, 1992f)
B	Partition coefficient	Contaminant-specific	(EPA, 1992f)

The estimated RME hazard index for an industrial/commercial adult exposed to subsurface soil at Site 1 was 0.04 from the ingestion pathway, which was below the acceptable level of 1.0 (Table 6-32). The estimated RME hazard index for a hypothetical future residential child exposed to Site 1 subsurface soil was 2.2 from the ingestion pathway, which was above the acceptable level of 1.0 (Table 6-33).

6.4.6.2 Site 2 Soils

For Site 2 surface soil, the estimated RME hazard index for an industrial/commercial adult was 0.05, below the acceptable level of 1.0 (Table 6-34). The estimated RME hazard index for a hypothetical future residential child exposed to surface soil at Site 2 was 1.19 from the ingestion pathway, which is above the acceptable level of 1.0 (Table 6-35).

The estimated RME hazard index for an industrial/commercial adult exposed to Site 2 subsurface soil was 0.04 from the ingestion pathway, which was below the acceptable level of 1.0 (Table 6-36). The estimated RME hazard index for a hypothetical future residential child exposed to Site 2 subsurface soil was 2.07 from the ingestion pathway, which was above the acceptable level of 1.0 (Table 6-37).

6.4.6.3 Site 3 Soils

The estimated RME hazard index for an industrial/commercial adult exposed to surface soil at Site 3 was not calculated because no COPCs failed screening criteria. The estimated RME hazard index for a hypothetical future residential child exposed to surface soil at Site 3 was 1.11 from the ingestion pathway, which is above the acceptable level of 1.0 (Table 6-38).

The estimated RME hazard index for an industrial/commercial adult exposed to subsurface soil at Site 3 was 0.03 from the ingestion pathway, which was below the acceptable level of 1.0 (Table 6-39). The estimated RME hazard index for a hypothetical future residential child exposed to Site 3 subsurface soil was 5.01 from the ingestion pathway, which was above the acceptable level of 1.0 (Table 6-40).

6.4.6.4 Impoundment Area Subsurface Soil

The estimated RME hazard index for an industrial/commercial adult exposed to subsurface soil at the Impoundment Area was 0.10 from the ingestion pathway, which was below the acceptable level of 1.0 (Table 6-41). The estimated RME hazard index for a hypothetical future residential child exposed to Impoundment Area subsurface soil was 2.67 from the ingestion pathway, which was above the acceptable level of 1.0 (Table 6-42).

TABLE 6-32
CALCULATION OF NON-CANCER HAZARDS - ADULT INDUSTRIAL WITH SITE 1 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Site 1
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose (2)	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	CHROMIUM VI	233.00	mg/kg	233.00	mg/kg	1	1.1E-04	mg/kg/day	3.0E-03	mg/kg/day	3.0E-03	mg/kg/day	0.04
												Total Hazard Index Across All Exposure Routes/Pathways	0.04

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.
(2) Specify if subchronic.

TABLE 6-33
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH SITE 1 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact with Site 1 Subsurface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Antimony	3.60E+00	mg/kg	3.60E+00	mg/kg	M	4.60E-05	mg/kg-day	4.00E-04	mg/kg-day	N/A	N/A	0.12
	Cadmium	1.55E+01	mg/kg	1.55E+01	mg/kg	M	1.98E-04	mg/kg-day	1.00E-03	mg/kg-day	N/A	N/A	0.20
	Chromium	2.33E+02	mg/kg	2.33E+02	mg/kg	M	2.98E-03	mg/kg-day	3.00E-03	mg/kg-day	N/A	N/A	0.99
	Manganese	1.26E+03	mg/kg	1.26E+03	mg/kg	M	1.61E-02	mg/kg-day	2.40E-02	mg/kg-day	N/A	N/A	0.67
	Mercury	4.60E-01	mg/kg	4.60E-01	mg/kg	M	5.88E-06	mg/kg-day	1.00E-04	mg/kg-day	N/A	N/A	0.06
	Silver	1.70E+01	mg/kg	1.70E+01	mg/kg	M	2.17E-04	mg/kg-day	5.00E-03	mg/kg-day	N/A	N/A	0.04
	Thallium	6.90E-01	mg/kg	6.90E-01	mg/kg	M	8.82E-06	mg/kg-day	7.00E-05	mg/kg-day	N/A	N/A	0.13
												Total of Routes	2.21

TABLE 6-34
CALCULATION OF NON-CANCER HAZARDS - ADULT INDUSTRIAL WORKER CONTACT WITH SITE 2 SURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact with Site 2 Surface Soil
Receptor Population: Industrial Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Cadmium	7.70E+00	mg/kg	7.70E+00	mg/kg	M	3.77E-06	mg/kg-day	1.00E-03	mg/kg-day	N/A	N/A	0.00
	Chromium	8.76E+01	mg/kg	8.76E+01	mg/kg	M	4.29E-05	mg/kg-day	3.00E-03	mg/kg-day	N/A	N/A	0.01
	Copper	1.61E+02	mg/kg	1.61E+02	mg/kg	M	7.88E-05	mg/kg-day	4.00E-02	mg/kg-day	N/A	N/A	0.00
	Silver	2.33E+01	mg/kg	2.33E+01	mg/kg	M	1.14E-05	mg/kg-day	5.00E-03	mg/kg-day	N/A	N/A	0.00
	Thallium	6.80E-01	mg/kg	6.80E-01	mg/kg	M	3.33E-07	mg/kg-day	7.00E-05	mg/kg-day	N/A	N/A	0.00
	Vanadium	4.60E+01	mg/kg	4.60E+01	mg/kg	M	2.25E-05	mg/kg-day	7.00E-03	mg/kg-day	N/A	N/A	0.00
	Zinc	4.28E+02	mg/kg	4.28E+02	mg/kg	M	2.09E-04	mg/kg-day	3.00E-01	mg/kg-day	N/A	N/A	0.00
	Aroclor-1254	5.96E+02	ug/kg	5.96E+02	ug/kg	M	2.92E-07	mg/kg-day	2.00E-05	mg/kg-day	N/A	N/A	0.01
												Total of Routes	0.05

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.

TABLE 6-35
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH SITE 2 SURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact with Site 2 Surface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Cadmium	7.70E+00	mg/kg	7.70E+00	mg/kg	M	9.84E-05	mg/kg-day	1.00E-03	mg/kg-day	N/A	N/A	0.10
	Chromium	8.76E+01	mg/kg	8.76E+01	mg/kg	M	1.12E-03	mg/kg-day	3.00E-03	mg/kg-day	N/A	N/A	0.37
	Copper	1.61E+02	mg/kg	1.61E+02	mg/kg	M	2.06E-03	mg/kg-day	4.00E-02	mg/kg-day	N/A	N/A	0.05
	Silver	2.33E+01	mg/kg	2.33E+01	mg/kg	M	2.98E-04	mg/kg-day	5.00E-03	mg/kg-day	N/A	N/A	0.06
	Thallium	6.80E-01	mg/kg	6.80E-01	mg/kg	M	8.69E-06	mg/kg-day	7.00E-05	mg/kg-day	N/A	N/A	0.12
	Vanadium	4.60E+01	mg/kg	4.60E+01	mg/kg	M	5.88E-04	mg/kg-day	7.00E-03	mg/kg-day	N/A	N/A	0.08
	Zinc	4.28E+02	mg/kg	4.28E+02	mg/kg	M	5.47E-03	mg/kg-day	3.00E-01	mg/kg-day	N/A	N/A	0.02
	Aroclor-1254	5.96E+02	ug/kg	5.96E+02	ug/kg	M	7.62E-06	mg/kg-day	2.00E-05	mg/kg-day	N/A	N/A	0.38
	Benz(a)anthracene	2.20E+03	ug/kg	2.20E+03	ug/kg	M	2.81E-05	mg/kg-day	--	mg/kg-day	N/A	N/A	--
	Benzo(a)pyrene	2.59E+03	ug/kg	2.59E+03	ug/kg	M	3.31E-05	mg/kg-day	--	mg/kg-day	N/A	N/A	--
	Benzo(b)fluoranthene	4.84E+03	ug/kg	4.84E+03	ug/kg	M	6.19E-05	mg/kg-day	--	mg/kg-day	N/A	N/A	--
	Indeno(1,2,3-cd)pyrene	1.72E+03	ug/kg	1.72E+03	ug/kg	M	2.20E-05	mg/kg-day	--	mg/kg-day	N/A	N/A	--
													1.19
												Total of Routes	1.19

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.

TABLE 6-36
CALCULATION OF NON-CANCER HAZARDS - ADULT INDUSTRIAL CONTACT WITH SITE 2 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Site 2
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose (2)	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	ANTIMONY	11.47	mg/kg	11.47	mg/kg	1	5.6E-06	mg/kg/day	4.0E-04	mg/kg/day	4.0E-04	mg/kg/day	0.01
	ARSENIC	6.26	mg/kg	6.26	mg/kg	1	3.1E-06	mg/kg/day	3.0E-04	mg/kg/day	3.0E-04	mg/kg/day	0.01
	CADMIUM	7.70	mg/kg	7.70	mg/kg	1	3.8E-06	mg/kg/day	1.0E-03	mg/kg/day	1.0E-03	mg/kg/day	0.00
	CHROMIUM VI	95.00	mg/kg	95.00	mg/kg	1	4.7E-05	mg/kg/day	3.0E-03	mg/kg/day	3.0E-03	mg/kg/day	0.02
												Total Hazard Index Across All Exposure Routes/Pathways	0.04

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.
(2) Specify if subchronic.

TABLE 6-37
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH SITE 2 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact with Site 2 Subsurface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Aluminum	1.66E+04	mg/kg	1.66E+04	mg/kg	M	2.12E-01	mg/kg-day	1.00E+00	mg/kg-day	N/A	N/A	0.21
	Antimony	1.15E+01	mg/kg	1.15E+01	mg/kg	M	1.47E-04	mg/kg-day	4.00E-04	mg/kg-day	N/A	N/A	0.37
	Arsenic	6.26E+00	mg/kg	6.26E+00	mg/kg	M	8.00E-05	mg/kg-day	3.00E-04	mg/kg-day	N/A	N/A	0.27
	Barium	1.21E+02	mg/kg	1.21E+02	mg/kg	M	1.55E-03	mg/kg-day	7.00E-02	mg/kg-day	N/A	N/A	0.02
	Cadmium	7.70E+00	mg/kg	7.70E+00	mg/kg	M	9.84E-05	mg/kg-day	1.00E-03	mg/kg-day	N/A	N/A	0.10
	Chromium	9.50E+01	mg/kg	9.50E+01	mg/kg	M	1.21E-03	mg/kg-day	3.00E-03	mg/kg-day	N/A	N/A	0.40
	Copper	3.96E+02	mg/kg	3.96E+02	mg/kg	M	5.06E-03	mg/kg-day	4.00E-02	mg/kg-day	N/A	N/A	0.13
	Manganese	5.83E+02	mg/kg	5.83E+02	mg/kg	M	7.45E-03	mg/kg-day	2.40E-02	mg/kg-day	N/A	N/A	0.31
	Nickel	1.87E+01	mg/kg	1.87E+01	mg/kg	M	2.39E-04	mg/kg-day	2.00E-02	mg/kg-day	N/A	N/A	0.01
	Silver	1.24E+01	mg/kg	1.24E+01	mg/kg	M	1.59E-04	mg/kg-day	5.00E-03	mg/kg-day	N/A	N/A	0.03
	Thallium	5.10E-01	mg/kg	5.10E-01	mg/kg	M	6.52E-06	mg/kg-day	7.00E-05	mg/kg-day	N/A	N/A	0.09
	Vanadium	4.14E+01	mg/kg	4.14E+01	mg/kg	M	5.29E-04	mg/kg-day	7.00E-03	mg/kg-day	N/A	N/A	0.08
	Zinc	5.35E+02	mg/kg	5.35E+02	mg/kg	M	6.84E-03	mg/kg-day	3.00E-01	mg/kg-day	N/A	N/A	0.02
	Aroclor-1254	3.75E+01	ug/kg	3.75E+01	ug/kg	M	4.79E-07	mg/kg-day	2.00E-05	mg/kg-day	N/A	N/A	0.02
	Aroclor-1260	6.53E+01	ug/kg	6.53E+01	ug/kg	M	8.35E-07	mg/kg-day	--	mg/kg-day	N/A	N/A	--
												Total of Routes	2.07

TABLE 6-38
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH SITE 3 SURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future (Hypothetical)
Medium: Soil
Exposure Medium: Surface
Exposure Point: Site 3
Receptor Population: Residential
Receptor Age: Child (0-6 years)

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose (2)	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	CHROMIUM VI	36.80	mg/kg	36.80	mg/kg	1	4.7E-04	mg/kg/day	3.0E-03	mg/kg/day	3.0E-03	mg/kg/day	0.16
	MANGANESE	1180.00	mg/kg	1180.00	mg/kg	1	1.5E-02	mg/kg/day	2.0E-02	mg/kg/day	2.0E-02	mg/kg/day	0.76
	THALLIUM	1.1	mg/kg	1.1	mg/kg	1	1.4E-05	mg/kg/day	7.0E-05	mg/kg/day	7.0E-05	mg/kg/day	0.20
												Total Hazard Index Across All Exposure Routes/Pathways	1.11

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.
(2) Specify if subchronic.

TABLE 6-39
CALCULATION OF NON-CANCER HAZARDS - ADULT INDUSTRIAL WORKER CONTACT WITH SITE 3 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact with Site 3 Subsurface Soil
Receptor Population: Industrial Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Arsenic	6.74E+00	mg/kg	6.74E+00	mg/kg	M	3.30E-06	mg/kg-day	3.00E-04	mg/kg-day	N/A	N/A	0.01
	Aroclor-1254	5.97E+02	ug/kg	5.97E+02	ug/kg	M	2.92E-07	mg/kg-day	2.00E-05	mg/kg-day	N/A	N/A	0.01
												Total of Routes	0.03

TABLE 6-40
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH SITE 3 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact with Site 3 Subsurface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	Antimony	9.67E+00	mg/kg	9.67E+00	mg/kg	M	1.24E-04	mg/kg-day	4.00E-04	mg/kg-day	N/A	N/A	0.31
	Arsenic	6.74E+00	mg/kg	6.74E+00	mg/kg	M	8.62E-05	mg/kg-day	3.00E-04	mg/kg-day	N/A	N/A	0.29
	Barium	4.19E+02	mg/kg	4.19E+02	mg/kg	M	5.36E-03	mg/kg-day	7.00E-02	mg/kg-day	N/A	N/A	0.08
	Cadmium	3.29E+01	mg/kg	3.29E+01	mg/kg	M	4.21E-04	mg/kg-day	1.00E-03	mg/kg-day	N/A	N/A	0.42
	Chromium	3.97E+01	mg/kg	3.97E+01	mg/kg	M	5.08E-04	mg/kg-day	3.00E-03	mg/kg-day	N/A	N/A	0.17
	Copper	1.39E+03	mg/kg	1.39E+03	mg/kg	M	1.78E-02	mg/kg-day	4.00E-02	mg/kg-day	N/A	N/A	0.44
	Manganese	1.07E+03	mg/kg	1.07E+03	mg/kg	M	1.37E-02	mg/kg-day	2.40E-02	mg/kg-day	N/A	N/A	0.57
	Mercury	8.20E+00	mg/kg	8.20E+00	mg/kg	M	1.05E-04	mg/kg-day	1.00E-04	mg/kg-day	N/A	N/A	1.05
	Nickel	4.47E+01	mg/kg	4.47E+01	mg/kg	M	5.72E-04	mg/kg-day	2.00E-02	mg/kg-day	N/A	N/A	0.03
	Silver	3.68E+02	mg/kg	3.68E+02	mg/kg	M	4.71E-03	mg/kg-day	5.00E-03	mg/kg-day	N/A	N/A	0.94
	Thallium	4.70E-01	mg/kg	4.70E-01	mg/kg	M	6.01E-06	mg/kg-day	7.00E-05	mg/kg-day	N/A	N/A	0.09
	Vanadium	5.90E+01	mg/kg	5.90E+01	mg/kg	M	7.54E-04	mg/kg-day	7.00E-03	mg/kg-day	N/A	N/A	0.11
	Zinc	1.97E+03	mg/kg	1.97E+03	mg/kg	M	2.52E-02	mg/kg-day	3.00E-01	mg/kg-day	N/A	N/A	0.08
	Aldrin	1.23E+02	ug/kg	1.23E+02	ug/kg	M	1.57E-06	mg/kg-day	3.00E-05	mg/kg-day	N/A	N/A	0.05
	Aroclor-1254	5.97E+02	ug/kg	5.97E+02	ug/kg	M	7.63E-06	mg/kg-day	2.00E-05	mg/kg-day	N/A	N/A	0.38
												Total of Routes	5.01

TABLE 6-41

CALCULATION OF NON-CANCER HAZARDS - ADULT INDUSTRIAL CONTACT WITH IMPOUNDMENT AREA SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Impoundment area
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose (2)	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	ANTIMONY	21.11	mg/kg	21.11	mg/kg	1	1.0E-05	mg/kg/day	4.0E-04	mg/kg/day	4.0E-04	mg/kg/day	0.03
	CHROMIUM VI	243.58	mg/kg	243.58	mg/kg	1	1.2E-04	mg/kg/day	3.0E-03	mg/kg/day	3.0E-03	mg/kg/day	0.04
	MANGANESE	1355.14	mg/kg	1355.14	mg/kg	1	6.6E-04	mg/kg/day	2.0E-02	mg/kg/day	2.0E-02	mg/kg/day	0.03
												Total Hazard Index Across All Exposure Routes/Pathways	0.10

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.

(2) Specify if subchronic.

TABLE 6-42
CALCULATION OF NON-CANCER HAZARDS - CHILD RESIDENT CONTACT WITH IMPOUNDMENT AREA SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future (Hypothetical)
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Impoundment area
Receptor Population: Residential
Receptor Age: Child (0-6 years)

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Hazard Calculation (1)	Intake (Non-Cancer)	Intake (Non-Cancer) Units	Reference Dose (2)	Reference Dose Units	Reference Concentration	Reference Concentration Units	Hazard Quotient
Ingestion	ANTIMONY	21.11	mg/kg	21.11	mg/kg	1	2.7E-04	mg/kg/day	4.0E-04	mg/kg/day	4.0E-04	mg/kg/day	0.68
	CADMIUM	3.56	mg/kg	3.56	mg/kg	1	4.6E-05	mg/kg/day	1.0E-03	mg/kg/day	1.0E-03	mg/kg/day	0.05
	CHROMIUM VI	243.58	mg/kg	243.58	mg/kg	1	3.1E-03	mg/kg/day	3.0E-03	mg/kg/day	3.0E-03	mg/kg/day	1.04
	COPPER	34.67	mg/kg	34.67	mg/kg	1	4.4E-04	mg/kg/day	4.0E-02	mg/kg/day	4.0E-02	mg/kg/day	0.01
	MANGANESE	1355.14	mg/kg	1355.14	mg/kg	1	1.7E-02	mg/kg/day	2.0E-02	mg/kg/day	2.0E-02	mg/kg/day	0.87
	MERCURY	0.11	mg/kg	0.11	mg/kg	1	1.4E-06	mg/kg/day	1.0E-04	mg/kg/day	1.0E-04	mg/kg/day	0.01
	SILVER	7.23	mg/kg	7.23	mg/kg	1	9.2E-05	mg/kg/day	5.0E-03	mg/kg/day	5.0E-03	mg/kg/day	0.02
												Total Hazard Index Across All Exposure Routes/Pathways	2.67

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for hazard calculation.
(2) Specify if subchronic.

6.4.7 Site-Specific Carcinogenic Risks for Soils

Carcinogenic risks estimated for potential receptors are discussed below and in the appropriate tables.

6.4.7.1 Site 1 Soils

The RME cancer risks for an industrial adult and a hypothetical future residential child exposed to Site 1 surface soil was not calculated because no COPCs failed screening criteria. The RME cancer risks for an industrial/commercial adult and for a hypothetical future residential child exposed to subsurface soil at Site 1 were also not calculated for the same reason.

6.4.7.2 Site 2 Soils

The RME cancer risk for an industrial/commercial adult exposed to surface soil at Site 2 was not calculated as there were no COPCs that failed the risk ratio screening process. The RME cancer risk for a hypothetical future residential child exposed to Site 2 surface soil was estimated at 2.9×10^{-5} from the ingestion pathway, which is within EPA's target risk range of 10^{-4} to 10^{-6} (Table 6-43).

The RME cancer risk for an industrial/commercial adult exposed to Site 2 subsurface soil was not calculated because no COPCs failed the risk ratio screening process. The RME cancer risk for a hypothetical future residential child exposed to subsurface soil at Site 2 was estimated at 2.23×10^{-5} from the ingestion pathway, which is within EPA's target risk range (Table 6-44).

6.4.7.3 Site 3 Soils

The RME cancer risks for an industrial/commercial adult and for a hypothetical future residential child exposed to surface soil at Site 3 were not calculated because no COPCs failed screening criteria.

The RME cancer risk for an industrial/commercial adult exposed to Site 3 subsurface soil was estimated at 5.58×10^{-5} from the ingestion pathway, which is within EPA's target risk range of 10^{-4} to 10^{-6} (Table 6-45). The RME cancer risk for a hypothetical future residential child exposed to subsurface soil at Site 3 was estimated at 3.55×10^{-4} from the ingestion pathway, which is above EPA's target risk range (Table 6-46).

6.4.7.4 Impoundment Area Subsurface Soil

The RME cancer risk for an industrial/commercial adult exposed to subsurface soil at the Impoundment Area was not calculated because no COPCs failed screening criteria. The RME cancer risk for a

TABLE 6-43
CALCULATION OF CANCER RISKS - CHILD RESIDENT CONTACT WITH SITE 2 SURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINTER, PENNSYVANIA

Scenario Timeframe: Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: Contact with Site 2 Surface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation (1)	Intake (Cancer)	Intake (Cancer) Units	Cancer Slope Factor	Cancer Slope Factor Units	Cancer Risk
Ingestion	Cadmium	7.70E+00	mg/kg	7.70E+00	mg/kg	M	8.44E-06	mg/kg-day	--	1/(mg/kg-day)	--
	Chromium	8.76E+01	mg/kg	8.76E+01	mg/kg	M	9.60E-05	mg/kg-day	--	1/(mg/kg-day)	--
	Copper	1.61E+02	mg/kg	1.61E+02	mg/kg	M	1.76E-04	mg/kg-day	--	1/(mg/kg-day)	--
	Silver	2.33E+01	mg/kg	2.33E+01	mg/kg	M	2.55E-05	mg/kg-day	--	1/(mg/kg-day)	--
	Thallium	6.80E-01	mg/kg	6.80E-01	mg/kg	M	7.45E-07	mg/kg-day	--	1/(mg/kg-day)	--
	Vanadium	4.60E+01	mg/kg	4.60E+01	mg/kg	M	5.04E-05	mg/kg-day	--	1/(mg/kg-day)	--
	Zinc	4.28E+02	mg/kg	4.28E+02	mg/kg	M	4.69E-04	mg/kg-day	--	1/(mg/kg-day)	--
	Aroclor-1254	5.96E+02	ug/kg	5.96E+02	ug/kg	M	6.53E-07	mg/kg-day	2.00E+00	1/(mg/kg-day)	1.31E-06
	Benz(a)anthracene	2.20E+03	ug/kg	2.20E+03	ug/kg	M	2.41E-06	mg/kg-day	7.30E-01	1/(mg/kg-day)	1.76E-06
	Benzo(a)pyrene	2.59E+03	ug/kg	2.59E+03	ug/kg	M	2.84E-06	mg/kg-day	7.30E+00	1/(mg/kg-day)	2.07E-05
	Benzo(b)fluoranthene	4.84E+03	ug/kg	4.84E+03	ug/kg	M	5.30E-06	mg/kg-day	7.30E-01	1/(mg/kg-day)	3.87E-06
	Indeno(1,2,3-cd)pyrene	1.72E+03	ug/kg	1.72E+03	ug/kg	M	1.88E-06	mg/kg-day	7.30E-01	1/(mg/kg-day)	1.38E-06
	(Total)										2.90E-05
										Total of Routes	2.90E-05

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for risk calculation.

TABLE 6-44
CALCULATION OF CANCER RISKS - CHILD RESIDENT CONTACT WITH SITE 2 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Suburface Soil
Exposure Medium: Subsurface Soil
Exposure Point: Contact with Site 2 Subsurface Soil
Receptor Population: Resident
Receptor Age: Child

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation (1)	Intake (Cancer)	Intake (Cancer) Units	Cancer Slope Factor	Cancer Slope Factor Units	Cancer Risk
Ingestion	Arsenic	6.26E+00	mg/kg	6.26E+00	mg/kg	M	6.86E-06	mg/kg-day	1.50E+00	1/(mg/kg-day)	1.03E-05
	Aroclor-1254	3.75E+01	ug/kg	3.75E+01	ug/kg	M	4.11E-08	mg/kg-day	2.00E+00	1/(mg/kg-day)	8.22E-08
	Aroclor-1260	6.53E+01	ug/kg	6.53E+01	ug/kg	M	7.16E-08	mg/kg-day	2.00E+00	1/(mg/kg-day)	1.43E-07
	Benz(a)anthracene	8.82E+02	ug/kg	8.82E+02	ug/kg	M	9.67E-07	mg/kg-day	7.30E-01	1/(mg/kg-day)	7.06E-07
	Benzo(a)pyrene	8.10E+02	ug/kg	8.10E+02	ug/kg	M	8.88E-07	mg/kg-day	7.30E+00	1/(mg/kg-day)	6.48E-06
	Benzo(b)fluoranthene	9.41E+02	ug/kg	9.41E+02	ug/kg	M	1.03E-06	mg/kg-day	7.30E-01	1/(mg/kg-day)	7.53E-07
	Dibenz(a,h)anthracene	4.17E+02	ug/kg	4.17E+02	ug/kg	M	4.57E-07	mg/kg-day	7.30E+00	1/(mg/kg-day)	3.34E-06
	Indeno(1,2,3-cd)pyrene	6.36E+02	ug/kg	6.36E+02	ug/kg	M	6.97E-07	mg/kg-day	7.30E-01	1/(mg/kg-day)	5.09E-07
										Total of Routes	2.23E-05

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for risk calculation.

TABLE 6-45
CALCULATION OF CANCER RISKS - ADULT INDUSTRIAL CONTACT WITH SITE 3 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Site 3
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation (1)	Intake (Cancer)	Intake (Cancer) Units	Cancer Slope Factor	Cancer Slope Factor Units	Cancer Risk
Ingestion	ARSENIC	6.74	mg/kg	6.74	mg/kg	1	1.18E-06	mg/kg/day	1.50E+00	mg/kg/day	1.77E-06
	BENZ[A]ANTHRACENE	37.13	mg/kg	37.13	mg/kg	1	6.49E-06	mg/kg/day	7.30E-01	mg/kg/day	4.74E-06
	BENZO[A]PYRENE	24.55	mg/kg	24.55	mg/kg	1	4.29E-06	mg/kg/day	7.30E+00	mg/kg/day	3.13E-05
	BENZO[B]FLUORANTHENE	35.98	mg/kg	35.98	mg/kg	1	6.29E-06	mg/kg/day	7.30E-01	mg/kg/day	4.59E-06
	DIBENZ[A,H]ANTHRACENE	9.29	mg/kg	9.29	mg/kg	1	1.62E-06	mg/kg/day	7.30E+00	mg/kg/day	1.18E-05
	INDENO[1,2,3-C,D]PYRENE	10.71	mg/kg	10.71	mg/kg	1	1.9E-06	mg/kg/day	7.30E-01	mg/kg/day	1.37E-06
	AROCLOR-1254	0.60	mg/kg	0.60	mg/kg	1E+00	1.0E-07	mg/kg/day	2.00E+00	mg/kg/day	2.08E-07
											5.6E-05

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for risk calculation.

TABLE 6-46
CALCULATION OF CANCER RISKS - CHILD RESIDENT CONTACT WITH SITE 3 SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future (Hypothetical)
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Site 3
Receptor Population: Residential
Receptor Age: Child (0-6 years)

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation (1)	Intake (Cancer)	Intake (Cancer) Units	Cancer Slope Factor	Cancer Slope Factor Units	Cancer Risk
Ingestion	ARSENIC	6.74	mg/kg	6.74	mg/kg	1	7.39E-06	mg/kg/day	1.50E+00	mg/kg/day	1.11E-05
	BENZ[A]ANTHRACENE	37.13	mg/kg	37.13	mg/kg	1	4.07E-05	mg/kg/day	7.30E-01	mg/kg/day	2.97E-05
	BENZO[A]PYRENE	24.55	mg/kg	24.55	mg/kg	1	2.69E-05	mg/kg/day	7.30E+00	mg/kg/day	1.96E-04
	BENZO[B]FLUORANTHENE	35.98	mg/kg	35.98	mg/kg	1	3.94E-05	mg/kg/day	7.30E-01	mg/kg/day	2.88E-05
	BENZO[K]FLUORANTHENE	32.96	mg/kg	32.96	mg/kg	1	3.61E-05	mg/kg/day	7.30E-02	mg/kg/day	2.64E-06
	DIBENZ[A,H]ANTHRACENE	9.29	mg/kg	9.29	mg/kg	1	1.0E-05	mg/kg/day	7.30E+00	mg/kg/day	7.45E-05
	INDENO[1,2,3-C,D]PYRENE	10.71	mg/kg	10.71	mg/kg	1	1.17E-05	mg/kg/day	7.30E-01	mg/kg/day	8.54E-06
	ALDRIN	0.12	mg/kg	0.12	mg/kg	1	1.4E-07	mg/kg/day	1.70E+01	mg/kg/day	2.30E-06
	AROCLOR-1254	0.60	mg/kg	0.60	mg/kg	1	6.5E-07	mg/kg/day	2.00E+00	mg/kg/day	1.31E-06
											3.6E-04

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for risk calculation.

residential child exposed to subsurface soil was estimated at 4.14×10^{-6} from the ingestion pathway which is within the target risk range (Table 6-47).

6.4.8 Sediment Risks

Tables 6-48 and 6-49 present estimated noncarcinogenic HQs and carcinogenic risks, respectively, to recreational children exposed to sediment via wading. The individual noncarcinogenic HQs were less than 1.0 for ingestion and dermal contact with COCs in sediment at Area A by recreational child receptors. The combined estimated cancer risks were 1.5×10^{-6} for ingestion and 3.1×10^{-7} for dermal contact for recreational child receptors.

6.4.9 Surface Water Risks

Tables 6-50 and 6-51 present estimated noncarcinogenic HQs and carcinogenic risks, respectively, to recreational children exposed to Area A surface water via wading. The individual noncarcinogenic HQs were less than 1.0 for ingestion and dermal contact with COCs in surface water by recreational child receptors. The estimated cancer risks are less than 1.0×10^{-6}. This is below the target risk range.

6.5 LEAD RISKS

6.5.1 Blood-Lead Modeling

As outlined in OSWER Directive 9355.4-12, EPA (1994a) has developed an approach to evaluating lead risks that recognizes the multimedia nature of lead exposures, incorporating absorption and pharmacokinetic information. Research has been conducted concerning lead intake and resultant blood-lead levels. Determinations of lead uptake from several sources (including soil and drinking water) were considered. Potential blood-lead level increases are estimated and are discussed, along with the potential implications of blood-lead results for residential children. The following discussion presents information that is useful in estimating lead exposure for surface soil exposure.

No threshold has been defined for effects related to blood-lead increases. Effects below blood-lead levels of 10 ug/dL are difficult to define. Inhibition of certain enzymes involved in red blood cell metabolism has been reported to occur at 10 to 15 ug/dL and possibly lower. Small increases in blood pressure have been observed in adults with blood-lead levels down to 7 ug/dL (EPA, 1994b). The most sensitive subpopulation to effects below 7 ug/dL would be infants, whose early neurological development can be affected by blood-lead concentrations reportedly down to 5 ug/dL (EPA, 1994b). Lead is also a fairly common environmental contaminant and, for this reason, typical blood-lead levels in the population at large may already exceed the concentrations discussed here.

TABLE 6-47

CALCULATION OF CANCER RISKS - CHILD RESIDENT CONTACT WITH IMPOUNDMENT AREA SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future (Hypothetical)
Medium: Soil
Exposure Medium: Subsurface
Exposure Point: Impoundment area
Receptor Population: Residential
Receptor Age: Child (0-6 years)

Exposure Route	Chemical of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation (1)	Intake (Cancer)	Intake (Cancer) Units	Cancer Slope Factor	Cancer Slope Factor Units	Cancer Risk
Ingestion	BENZ[A]ANTHRACENE	0.37	mg/kg	0.37	mg/kg	1	4.05E-07	mg/kg/day	7.30E-01	mg/kg/day	2.96E-07
	BENZO[A]PYRENE	0.39	mg/kg	0.39	mg/kg	1	4.27E-07	mg/kg/day	7.30E+00	mg/kg/day	3.12E-06
	BENZO[B]FLUORANTHENE	0.41	mg/kg	0.41	mg/kg	1	4.49E-07	mg/kg/day	7.30E-01	mg/kg/day	3.28E-07
	INDENO[1,2,3-C,D]PYRENE	0.33	mg/kg	0.33	mg/kg	1	3.62E-07	mg/kg/day	7.30E-01	mg/kg/day	2.64E-07
	AROCLOR-1260	0.06	mg/kg	0.06	mg/kg	1	6.58E-08	mg/kg/day	2.00E+00	mg/kg/day	1.32E-07
											4.1E-06

(1) Specify Medium-Specific (M) or Route-Specific (R) EPC selected for risk calculation.

TABLE 6-48
NONCARCINOGENIC HQS, WADING, FUTURE RECREATIONAL RECEPTORS - AREA A
SEDIMENT
NAWC WARMINSTER, PA

SUBSTANCE	SEDIMENT INGESTION	SEDIMENT DERMAL CONTACT
4,4'-DDD	NA	NA
4,4'-DDE	NA	NA
4,4'-DDT	3.6E-05	1.8E-05
ALDRIN	7.2E-05	5.7E-05
ALPHA-CHLORDANE	NA	NA
AROCLOR-1016	1.9E-04	5.3E-05
AROCLOR-1248	NA	NA
AROCLOR-1254	1.4E-03	4.0E-04
AROCLOR-1260	NA	NA
DELTA-BHC	NA	NA
DIELDRIN	1.5E-05	1.2E-05
ENDOSULFAN II	2.8E-07	1.9E-07
ENDOSULFAN SULFATE	2.3E-07	1.8E-07
ENDRIN	1.1E-05	7.0E-06
ENDRIN ALDEHYDE	6.9E-06	5.5E-06
ENDRIN KETONE	5.1E-06	4.1E-06
GAMMA-CHLORDANE	1.0E-05	5.0E-06
2-METHYLNAPHTHALENE	NA	NA
4-METHYLPHENOL	4.3E-05	2.8E-05
ACENAPHTHENE	4.8E-06	3.8E-06
ACENAPHTHYLENE	NA	NA
ANTHRACENE	1.4E-06	8.7E-07
BENZ(A)ANTHRACENE	NA	NA
BENZO(A)PYRENE	NA	NA
BENZO(B)FLUORANTHENE	NA	NA
BENZO(G,H,I)PERYLENE	NA	NA
BENZO(K)FLUORANTHENE	NA	NA
BIS(2-ETHYLHEXYL)PHTHALA	2.7E-05	2.2E-05
BUTYL BENZYL PHTHALATE	2.9E-07	2.3E-07
CARBAZOLE	NA	NA
CHRYSENE	NA	NA
DI-N-BUTYL PHTHALATE	4.8E-07	1.9E-07
DI-N-OCTYL PHTHALATE	6.6E-06	5.2E-06
DIBENZ(A,H)ANTHRACENE	NA	NA
DIBENZOFURAN	6.4E-05	5.1E-05
FLUORANTHENE	7.6E-05	6.0E-05
FLUORENE	7.7E-06	6.1E-06
INDENO(1,2,3-CD)PYRENE	NA	NA
NAPHTHALENE	2.0E-06	1.2E-06
PYRENE	9.4E-05	5.7E-05
1,1,1-TRICHLOROETHANE	3.4E-09	1.0E-11
1,1-DICHLOROETHENE	5.1E-08	1.6E-10
1,2-DICHLOROETHENE (TOTA	3.1E-07	6.2E-10
2-BUTANONE	3.5E-09	7.0E-12
ACETONE	5.4E-08	8.0E-09
CARBON TETRACHLORIDE	4.1E-06	9.5E-09
CHLOROFORM	2.3E-07	4.5E-10
CHLOROMETHANE	NA	NA
ETHYLBENZENE	6.1E-09	9.1E-10
TETRACHLOROETHENE	5.0E-07	6.0E-08
TOLUENE	1.7E-08	2.1E-09
TRICHLOROETHENE	4.1E-06	4.9E-07
TOTAL XYLENES	1.1E-09	1.3E-10
ALUMINUM	1.4E-03	5.4E-05
ARSENIC	3.4E-03	1.4E-04
BARIUM	5.4E-04	5.4E-04
BERYLLIUM	3.8E-05	1.5E-04
CADMIUM	2.6E-03	2.0E-03
CHROMIUM	1.1E-05	2.3E-05
COBALT	5.6E-05	2.2E-06
COPPER	2.4E-04	1.6E-05
IRON	1.8E-02	7.1E-04
LEAD	NA	NA
MANGANESE	1.6E-02	2.1E-02
MERCURY	2.0E-04	1.2E-04
NICKEL	4.0E-04	1.1E-04
SELENIUM	1.5E-05	7.3E-07
SILVER	2.9E-05	5.7E-06
VANADIUM	1.1E-03	4.5E-03
ZINC	5.6E-04	8.9E-05

N/A = NOT APPLICABLE, NO TOXICITY VALUE HAS BEEN ESTABLISHED FOR THIS CHEMICAL

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TABLE 6-49
CARCINOGENIC RISK, WADING, FUTURE RECREATIONAL RECEPTORS - AREA A
SEDIMENT
NAWC WARMINSTER, PA

SUBSTANCE	SEDIMENT INGESTION	SEDIMENT DERMAL CONTACT
4,4'-DDD	1.0E-10	5.0E-11
4,4'-DDE	5.6E-11	2.8E-11
4,4'-DDT	5.2E-10	2.6E-10
ALDRIN	3.1E-09	2.5E-09
ALPHA-CHLORDANE	N/A	N/A
AROCLOR-1016	8.8E-09	2.5E-09
AROCLOR-1248	2.3E-08	6.5E-09
AROCLOR-1254	1.9E-08	5.3E-09
AROCLOR-1260	2.8E-08	7.7E-09
DELTA-BHC	N/A	N/A
DIELDRIN	1.0E-09	8.0E-10
ENDOSULFAN II	N/A	N/A
ENDOSULFAN SULFATE	N/A	N/A
ENDRIN	N/A	N/A
ENDRIN ALDEHYDE	N/A	N/A
ENDRIN KETONE	N/A	N/A
GAMMA-CHLORDANE	6.7E-11	3.3E-11
2-METHYLNAPHTHALENE	N/A	N/A
4-METHYLPHENOL	N/A	N/A
ACENAPHTHENE	N/A	N/A
ACENAPHTHYLENE	N/A	N/A
ANTHRACENE	N/A	N/A
BENZ(A)ANTHRACENE	9.6E-08	*
BENZO(A)PYRENE	7.8E-07	*
BENZO(B)FLUORANTHENE	1.1E-07	*
BENZO(G,H,I)PERYLENE	N/A	N/A
BENZO(K)FLUORANTHENE	5.2E-09	*
BIS(2-ETHYLHEXYL)PHTHALA	6.5E-10	5.2E-10
BUTYL BENZYL PHTHALATE	N/A	N/A
CARBAZOLE	6.2E-10	*
CHRYSENE	1.1E-09	*
DI-N-BUTYL PHTHALATE	N/A	N/A
DI-N-OCTYL PHTHALATE	N/A	N/A
DIBENZ(A,H)ANTHRACENE	1.7E-07	*
DIBENZOFURAN	N/A	*
FLUORANTHENE	N/A	N/A
FLUORENE	N/A	N/A
INDENO(1,2,3-CD)PYRENE	5.5E-08	*
NAPHTHALENE	N/A	N/A
PYRENE	N/A	N/A
1,1,1-TRICHLOROETHANE	N/A	N/A
1,1-DICHLOROETHENE	2.4E-11	7.2E-14
1,2-DICHLOROETHENE (TOTA	N/A	N/A
2-BUTANONE	N/A	N/A
ACETONE	N/A	N/A
CARBON TETRACHLORIDE	3.2E-11	7.4E-14
CHLOROFORM	1.2E-12	2.3E-15
CHLOROMETHANE	3.2E-12	5.1E-13
ETHYLBENZENE	N/A	N/A
TETRACHLOROETHENE	2.2E-11	2.7E-12
TOLUENE	N/A	N/A
TRICHLOROETHENE	2.3E-11	2.8E-12
TOTAL XYLENES	N/A	N/A
ALUMINUM	N/A	N/A
ARSENIC	1.3E-07	5.5E-09
BARIUM	N/A	N/A
BERYLLIUM	7.1E-08	2.8E-07
CADMIUM	N/A	N/A
CHROMIUM	N/A	N/A
COBALT	N/A	N/A
COPPER	N/A	N/A
IRON	N/A	N/A
LEAD	N/A	N/A
MANGANESE	N/A	N/A
MERCURY	N/A	N/A
NICKEL	N/A	N/A
SELENIUM	N/A	N/A
SILVER	N/A	N/A
VANADIUM	N/A	N/A
ZINC	N/A	N/A
TOTAL RISK	1.5E-06	3.1E-07

N/A = NOT APPLICABLE, NO TOXICITY VALUE HAS BEEN ESTABLISHED FOR THIS CHEMI
* CANCER RISK FOR PAHS NOT ESTIMATED FOR DERMAL EXPOSURE

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TABLE 6-50
NONCARCINOGENIC HQS, WADING, FUTURE RECREATIONAL RECEPTORS - AREA A
SURFACE WATER
NAWC WARMINSTER, PA

SUBSTANCE	SURFACE WATER INGESTION	SURFACE WATER DERMAL CONTACT
4,4'-DDD	N/A	N/A
4,4'-DDT	4.3E-06	3.3E-04
BENZ(A)ANTHRACENE	N/A	N/A
BENZO(B)FLUORANTHENE	N/A	N/A
CHRYSENE	N/A	N/A
DI-N-OCTYL PHTHALATE	1.5E-06	1.9E-04
DIETHYL PHTHALATE	3.8E-08	4.8E-06
FLUORANTHENE	1.2E-06	1.4E-04
PYRENE	1.5E-06	1.5E-04
1,1-DICHLOROETHANE	1.5E-06	9.1E-05
2-BUTANONE	1.0E-06	6.4E-05
BENZENE	N/A	N/A
BROMOMETHANE	5.5E-05	3.4E-03
CARBON DISULFIDE	8.4E-06	1.0E-03
CHLOROETHANE	1.2E-06	7.2E-05
CHLOROMETHANE	N/A	N/A
TETRACHLOROETHENE	1.5E-05	9.6E-04
TRICHLOROETHENE	5.1E-05	3.2E-03
ALUMINUM	1.8E-05	8.3E-07
BARIUM	3.1E-04	3.6E-04
CHROMIUM	5.0E-07	1.2E-06
COPPER	2.5E-04	1.9E-05
IRON	1.2E-03	5.8E-05
LEAD	N/A	N/A
MANGANESE	2.5E-03	4.0E-03
NICKEL	1.4E-04	4.4E-05
THALLIUM	3.0E-03	1.4E-04
ZINC	2.8E-05	5.3E-06

N/A = NOT APPLICABLE, NO TOXICITY VALUE HAS BEEN ESTABLISHED FOR THIS CHEMICA
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TABLE 6-51
CARCINOGENIC RISK, WADING, FUTURE RECREATIONAL RECEPTORS - AREA A
SURFACE WATER
NAWC WARMINSTER, PA

SUBSTANCE	SURFACE WATER INGESTION	SURFACE WATER DERMAL CONTACT
4,4'-DDD	2.9E-11	2.3E-09
4,4'-DDT	6.3E-11	4.9E-09
BENZ(A)ANTHRACENE	9.6E-10	*
BENZO(B)FLUORANTHENE	1.9E-09	*
CHRYSENE	1.9E-11	*
DI-N-OCTYL PHTHALATE	N/A	N/A
DIETHYL PHTHALATE	N/A	N/A
FLUORANTHENE	N/A	N/A
PYRENE	N/A	N/A
1,1-DICHLOROETHANE	N/A	N/A
2-BUTANONE	N/A	N/A
BENZENE	7.6E-11	4.8E-09
BROMOMETHANE	N/A	N/A
CARBON DISULFIDE	N/A	N/A
CHLOROETHANE	N/A	N/A
CHLOROMETHANE	6.8E-10	4.3E-08
TETRACHLOROETHENE	6.8E-10	4.3E-08
TRICHLOROETHENE	2.9E-10	1.8E-08
ALUMINUM	N/A	N/A
BARIUM	N/A	N/A
CHROMIUM	N/A	N/A
COPPER	N/A	N/A
IRON	N/A	N/A
LEAD	N/A	N/A
MANGANESE	N/A	N/A
NICKEL	N/A	N/A
THALLIUM	N/A	N/A
ZINC	N/A	N/A
TOTAL RISK	4.7E-09	1.2E-07

N/A = NOT APPLICABLE, NO TOXICITY VALUE HAS BEEN ESTABLISHED FOR THIS CHEMICA
* = DERMAL CONTACT WITH CARCINOGENIC PAHs IS NOT ESTIMATED

Dietary intake of lead is assumed to produce increases of 0.02 to 0.04 ug/dL blood lead per ug/day ingested by adults and 0.16 ug/dL blood lead per ug/day ingested by infants (EPA, 1986a). Blood-lead levels are estimated to increase by 0.6 to 6.8 ug/dL per 1,000 mg/kg lead in soil (EPA, 1986a).

Blood-lead levels in residential children (age 1 to 6) were estimated using the Integrated Exposure and Uptake Biokinetic (IEUBK) Model (version 0.99d) developed by EPA (EPA, 1994b). The model is applied using the average surface soil concentration at Area A. As discussed in Section 6.1.3.1, lead was selected as a COPC in surface soil in Site 2 (the maximum detection of lead was 994J mg/kg) and in subsurface soil at Site 2 and at Site 3 (the maximum detections of lead were 2,060 and 4,570 mg/kg, respectively). These values exceed the 400 mg/kg OSWER Directive benchmark criterion. Blood-lead levels in industrial or commercial workers were not estimated as part of the human health risk assessment since children were considered to be the most sensitive receptor to the effects related to blood-lead level increases.

For the assessment of ingestion of lead in surface soil by residential children, default values in the model are used to represent background lead concentrations in air, house dust, water, and the level of material contribution. Additionally, the model's default values are used to represent respiratory rate, soil and water ingestion rates, and the percent of lead absorption by the various exposure routes. The only site-specific factor entered into the IEUBK Model is the average lead concentration (108, 167, 330 mg/kg) in Site 2 surface soil, Site 2 subsurface soil, and Site 3 subsurface soil, respectively (the sites within Area A that failed screening).

The output of the IEUBK Model is a histogram that presents the estimated percentage of residential children (age 0 through 6 years) with a blood-lead level above 10 ug/dL (considered to be the threshold significance level above which adverse effects cannot be ruled out). When the percentage of the population estimated to have blood-levels above 10 ug/dL is greater than five percent, then EPA considers the potential for adverse effects to be significant (EPA, 1994a). This histogram, along with input information particular to each run of the IEUBK model, is presented in Appendix I. The estimated percentage of residential children (age 0 through 6 years) with a blood-lead level above 10 ug/dL is presented below.

6.5.2 Lead Risks

Lead was identified as a COPC in surface and subsurface soils at Site 2 and in subsurface soil at Site 3 in Area A. However, as previously discussed, lead was not quantitatively evaluated in the risk tables. This was necessary because EPA's approach to evaluating lead risks goes beyond providing a single point estimate output and incorporates absorption and pharmacokinetic properties. Section 6.3.4 discusses background information related to blood-lead estimation methods. Exposure to lead in surface soil was evaluated using the EPA IEUBK Lead Model, and those results are described below.

The average concentration of lead in Site 2 surface soil (108 mg/kg), Site 2 subsurface soil (167 mg/kg), and Site 3 subsurface soil (330 mg/kg) were used as input into the IEUBK Model. All other media inputs into the IEUBK Model were default parameters. The estimated percentages of residential children with a blood-lead level above 10 ug/dL were 0.26% for surface soil and 0.73% for subsurface soil at Site 2. These are below EPA's protective level cutoff of 5%. Adverse effects to residential children (age 1 to 6) are not expected from lead concentrations in subsurface soil at Site 2.

The estimated percentage of residential children with a blood lead level above 10 ug/dL was 7.75% for subsurface soil at Site 3. This is above EPA's protective level cutoff of 5%; however, the model also predicted that most children would have a blood-lead level of 5.24 ug/dl, which is below the EPA's protective level cutoff of 10 ug/dl. Therefore, adverse effects to residential children (age 1 to 6) may result from lead concentrations in subsurface soil at Site 3 might be unacceptable. The model histograms and model-specific input parameters are shown in Appendix I.

6.6 HUMAN HEALTH RISK ASSESSMENT CONCLUSIONS

No estimated carcinogenic risks or noncarcinogenic risks above EPA's target risk levels of 1×10^{-4} and 1.0, respectively, were present for the industrial/commercial scenario evaluated for COPCs in surface soil and subsurface soil in the human health risk assessment. These are the highest carcinogenic risks identified under intended reuse. These risks fall within EPA's target risk range of 1×10^{-4} to 1×10^{-6} and therefore may be considered acceptable. The estimated cancer risks associated with the most likely future land use scenario (industrial/commercial) were within the target risk range. A summary of all Area A carcinogenic and noncarcinogenic risks for each exposure scenario is presented in Table 6-52.

Both noncarcinogenic and carcinogenic risks above EPA's target risk levels of 1.0 and 1×10^{-4}, respectively, were estimated for the hypothetical future residential child scenario evaluated for COPCs in surface soil and subsurface soil. Specifically, non-cancer risks were identified in Site 2 surface soils, and in subsurface soils in all four sites at Area A. Cancer risks were identified in subsurface soils in Site 3. The removal action was not intended to remove contaminants to a level protective of this scenario, as the intended reuse is expected to be industrial/commercial. Therefore, deed restrictions might be required to limit reuse to industrial/commercial purposes. If the land use designation were to change in the future, quantitative risks estimated in this section should be re-evaluated.

TABLE 6-52

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs (POST-REMOVAL)

REASONABLE MAXIMUM EXPOSURE

NAWC WARMINSTER, PENNSYLVANIA

Scenario Timeframe: Future
Receptor Population: Residential
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Primary Target Organ	Ingestion	Inhalation	Dermal	Exposure Routes Total
Soil	Surface	Site 2	all	2.90E-05	N/A	N/A	2.90E-05	all		1.19	N/A	N/A	1.19
		Site 3	all	N/A	N/A	N/A	N/A	all		1.11	N/A	N/A	1.11
	Subsurface	Site 1	all	N/A	N/A	N/A	N/A	all		2.21	N/A	N/A	2.21
		Site 2	all	2.23E-05	N/A	N/A	2.23E-05	all		2.07	N/A	N/A	2.07
		Site 3	all	3.55E-04	N/A	N/A	3.55E-04	all		5.01	N/A	N/A	5.01
		Impoundment area	all	4.14E-06	N/A	N/A	4.14E-06	all		2.67	N/A	N/A	2.67

Scenario Timeframe: Future
Receptor Population: Industrial/Commercial
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Primary Target Organ	Ingestion	Inhalation	Dermal	Exposure Routes Total
Soil	Surface	Site 2	all	N/A	N/A	N/A	N/A	all		0.05	N/A	N/A	0.05
		Site 3	all	N/A	N/A	N/A	N/A	all		N/A	N/A	N/A	N/A
	Subsurface	Site 1	all	N/A	N/A	N/A	N/A	all		0.04	N/A	N/A	0.04
		Site 2	all	3.56E-06	N/A	N/A	3.56E-06	all		0.04	N/A	N/A	0.04
		Site 3	all	N/A	N/A	N/A	N/A	all		0.03	N/A	N/A	0.03
		Impoundment area	all	N/A	N/A	N/A	N/A	all		0.10	N/A	N/A	0.1

Scenario Timeframe: Future
Receptor Population: Recreational
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Primary Target Organ	Ingestion	Inhalation	Dermal	Exposure Routes Total
Stream	Surface Water		all	4.70E-09	N/A	1.20E-07	1.25E-07	all		2.80E-05	N/A	5.30E-06	3.33E-05
	Sediment		all	1.50E-06	N/A	3.10E-07	1.81E-06	all		5.60E-04	N/A	8.90E-05	6.49E-04

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The estimated percentages of residential children exposed to surface soil (0.26%) and subsurface soil (0.73%) at Site 2 with blood-lead levels above 10 ug/dl are below EPA's protective level cutoff of 5%. Therefore, lead levels in soils do not present an unacceptable risk at Site 2 to hypothetical future residential children. The estimated percentage of residential children exposed to subsurface soil (7.75%) at Site 3 with a blood-lead level above 10 ug/dl is above EPA's protective level cutoff of 5%. However, the model also predicted a blood lead level of 5.24 ug/dl for most children, which is below EPA's protective level cutoff of 10ug/dl. Therefore, lead levels in subsurface soil may present an unacceptable risk at Site 3 to hypothetical future residential children.

Estimated cancer and noncancer risks for recreational children exposed to surface water via wading and to sediment via ingestion and dermal contract were not found to be significant (i.e., all cancer risks less than 1.0×10^{-6}; all HQs less than 1.0) for nearby Area A surface water and sediment.

The presence of several PAHs and metals in nearby Area A stream sediments indicated the potential for a combined toxic effect to aquatic organisms. These potential risks to aquatic organisms may result in risks to semi-aquatic receptors that feed on them. This is of the most concern downstream of NAWC Warminster property, where aquatic habitat in the tributary and nearby wetlands increases in quality and quantity. Although nearby industrialized and off-base areas may contribute PAHs to the stream, the presence of highly elevated PAH concentrations adjacent to Area A suggests significant contaminant inputs from base-related activities.

6.7 UNCERTAINTY ANALYSIS FOR ASSESSING HUMAN HEALTH RISKS

The goal of the uncertainty analysis is to identify important uncertainties and limitations associated with the HHRA. Uncertainties are related to each of the main components of the assessment (i.e., data evaluation, dose-response assessment, exposure assessment, and risk characterization). The effect of a particular uncertainty on the outcome of the assessment (i.e., risk estimates) is also indicated, where possible.

As discussed in EPA (1989a), the risk measures used in Superfund site risk assessments are not fully probabilistic estimates of risk but rather are conditional estimates based on a considerable number of assumptions about exposure and toxicity. There are uncertainties associated with each aspect of risk assessment, from environmental data collection through risk characterization. To support decision-making processes, significant HHRA uncertainties are noted below.

6.7.1 Uncertainties Associated with Data Evaluation

Major uncertainties associated with data evaluation are discussed below. The areal extent of the samples (including the number collected and location of the sampling points) in a particular medium impacts the calculation of EPCs. Several removal actions for surface and subsurface soils were conducted in the vicinity of Area A. Every effort was made to collect samples (both recent samples and historical samples that were not excavated) that reflect actual site conditions and to include areas thought to contain the most significant contamination or exposure problems. This uncertainty is expected to be low for surface and subsurface soil data sets given the large number of soil samples collected over a relatively small site area. This uncertainty is expected to be higher for sediment and surface water samples given the small number of sampling locations in off-base locations near Area A.

Established data validation procedures were applied to define analytical uncertainties in terms of qualifying data as inaccurate or imprecise and to eliminate data points that are unusable for risk assessment. This treatment does not eliminate all uncertainty but focuses attention on potential areas of concern regarding accuracy and precision.

Uncertainties exist regarding selection of a concentration for input into the quantitative risk assessment. The use of the exposure point concentration to estimate risk is generally regarded as a conservative estimate since this entails using either the upper 95 percent confidence limit on the arithmetic mean (based on normal or log-transformed data distribution) or the maximum concentration. The use of the EPC as the input value into the quantitative risk assessment as a representation of site concentrations of COPCs generally lowers the chances of underestimating the actual risk present in a exposure pathway to a potential receptor. However, the use of the exposure point concentration may overestimate the actual risk present in an exposure pathway at a particular area of interest. To help avoid this problem, the maximum value was used in place of the upper 95 percent limit when the latter was larger.

The ability (power) of the W test to be able to correctly identify genuine differences between the shape of a sample population versus a reference normal or lognormal population is reduced when too few samples are collected. If an incorrect distributional assumption is made based on this test, this could lead to an over- or underestimate of the upper 95 percent UCL on the mean, which in turn would create some additional uncertainty as to whether the estimated risk is a reasonable approximation of high end exposure. To help limit the potential for overestimation , the maximum value was used in place of the upper 95 percent UCL on the mean when the latter was larger.

The chemical analytical database has some limitations regarding the representativeness of the laboratory results, the inclusion of nondetected data, data gaps, number of samples collected, and heterogeneity of sample data. The effects of these limitations on the results of the risk assessment are varied. However, every effort was made to collect and use samples that reflect actual site conditions. Nondetected results

were treated using one-half the detection limit in all statistical functions. These actions should minimize uncertainty in the database.

The use of screening concentrations that are based on a single route of exposure (i.e., ingestion) may lead to the underestimation of risks since they do not account for the additive effects across various exposure pathways. The resultant effects of the risks are not considered significant because conservative values, derived from a target HI of 0.1 for noncarcinogens and a target risk of 1×10^{-6} for carcinogens, were employed.

The use of residential surface soil screening concentrations for COPC selection under an industrial exposure scenario represents a conservative approach since exposure under an industrial scenario is expected to be lower than exposure under a residential scenario which are the basis of the RBC values. Consequently, COPCs may be selected that are not truly reflective of significant risk exposures under an industrial scenario which is evident from the noncarcinogenic and carcinogenic industrial risks estimated in the risk assessment.

The use of residential surface soil screening concentrations for COPC selection under an casual user exposure scenario represents a conservative approach since exposure under an casual user scenario is expected to be lower than exposure under a residential scenario which are the basis of the RBC values. Consequently, COPCs may be selected that are not truly reflective of significant risk exposures under an casual user scenario, which is evident from the estimated noncarcinogenic and carcinogenic casual user risks.

The use of residential surface soil screening concentrations for sediment COPC selection and residential tap water screening concentrations for surface water under a recreational exposure scenario represents a conservative approach since exposure under an recreational scenario is expected to be lower than exposure under a residential scenario which are the basis of the RBC values. Consequently, COPCs may be selected that are not truly reflective of significant risk exposures under an recreational user scenario that is evident from the estimated noncarcinogenic and carcinogenic recreational risks.

6.7.2 Uncertainties Associated with Exposure Estimates

Major uncertainties associated with identifying potential receptors, exposure routes, and exposure estimates are discussed below. The likelihood of the occurrence of the defined exposure scenarios is not always known. Identified land use and activity patterns at a site are limited to the observations made during the field investigation, known land uses in the surrounding area, and information provided by the Navy on anticipated future land use.

Several receptor characteristics, such as selection of casual user and recreational receptor age groups, exposure frequency, and exposure duration are generally based on professional judgment. There are limitations to using various models and/or equations to estimate exposure doses or contaminant concentrations. For example, modeled concentrations may not be indicative of actual site conditions during exposure.

In general, the underestimation of risks was prevented using conservative exposure assumptions and exposure concentrations. Maximum detected concentrations are sometimes used as EPCs in exposure pathways at the site. Although maximum concentrations are not a reasonable estimate of the concentration expected to be experienced by a receptor over time, the use of these values does provide a highly conservative estimate of risk to potential receptors.

The model for dermal exposure to sediment assumes that only a very thin, constant thickness layer of solid media is available for contaminant transfer to the stratum corneum and that a constant amount of contaminant, proportional to the soil or sediment concentration, will be absorbed per unit area of skin and per exposure event. However, adherence to skin varies with such factors as particle size, soil type, and organic carbon content. As estimated by EPA (1992e), the absorbed dermal dose could vary by as much as a factor of 50 from the model estimates, even assuming that activity patterns lead to the exposure duration applied in the experimental trials used to develop absorption factors.

Prediction of absorption rates for lipophilic compounds is difficult due to, among other reasons, the possibility of a second absorption pathway that depends on the lipid content of the stratum corneum at the application site. Experimental determination of absorption rates indicates that interspecies differences are considerable, which, along with other variability's related to condition and age of skin, differences in lag time, and site of application effects, yields appreciable uncertainty in estimated dermal exposures by using published chemical-specific permeation functions. In addition, literature data indicate a variation by as much as a factor of 300 in chemical absorption rates for skin in different anatomical areas of the body. It should also be noted that children generally have greater absorption rates than adults.

Exposure assumptions can add uncertainty into the risk assessment process based on input values selected for each exposure route. The rationale for each assumption was provided in each table of input parameters. Receptor characteristics, such as age and skin surface areas, are based on published values. Conservative values (based on reasonable maximum exposure or professional judgment) are used in most exposure equations, except where average values are expected to better correspond to actual site conditions.

6.7.3 Uncertainties Associated with Toxicological Evaluation

The major uncertainties associated with the toxicological evaluation, which was performed after the risk ratio analysis was conducted for post-removal surface and subsurface soils, are discussed in this section. There is uncertainty associated with the RfDs and SFs. The uncertainty results from the extrapolation of animal data to humans, the extrapolation of carcinogenic effects from the laboratory high-dose to the environmental low-dose scenarios, and interspecies and intraspecies variations in toxicological endpoints caused by chemical exposure. The use of EPA RfD values is generally considered to be conservative because the reference doses are based on no-effect or lowest-observed-effect levels and then further reduced with uncertainty factors to increase the margin of safety by a factor in the neighborhood of 10 to 1,000-fold.

The RfDs and SFs of some chemicals have not been established, and therefore toxicity could not be quantitatively assessed. In most cases, where RfDs were unavailable for carcinogens, the carcinogenic risk is considered to be much more significant since carcinogenic effects usually occur at much lower doses.

The uncertainty associated with the dermal exposure risk estimates is high because of the derivation of the dermal slope factor and reference dose. The dermal toxicity factors are based on default oral absorption factors. This can result in an over- or underestimation of the toxicity factors. It can cause the dermal exposure to be a primary contributor to the cumulative cancer risk and/or hazard index. The uncertainty associated with the dermal exposure route may overestimate the risk posed by the Area A sites.

Dermal carcinogenic risks were not estimated for PAHs. EPA (1989a) states that it is inappropriate to use the oral slope factor to evaluate the risks associated with dermal exposure to carcinogens such as benzo(a)pyrene, which cause cancer through direct action at the point of application. The uncertainty associated with not quantitatively evaluating these chemicals may underestimate the carcinogenic risk for Area A sites.

Nonthreshold (carcinogenic) effects are extrapolated from the high doses administered to laboratory animals to the low doses received under more common human exposure scenarios. Results of laboratory animal studies are extrapolated to human or environmental receptors.

There is considerable interspecies variation in toxicological endpoints used in characterizing potential health effects resulting from exposure to a chemical. In addition, there is considerable variability in sensitivity among individuals of any particular species. Short-time toxicological studies are used to predict long-term effects.

Established RfDs have an inherent amount of uncertainty. Some chemical-specific uncertainties are noted below.

Although the more restrictive basis for evaluating risk associated with exposure to arsenic is to assume it is a carcinogen, carcinogenic effects are not the primary health effects expected to be manifested upon exposure to arsenic. The preponderance of scientific information indicates that humans are capable of metabolizing arsenic to expedite its elimination from the body (ATSDR, 1988). Its elimination from the body obviously mitigates the possibility for arsenic to manifest carcinogenic effects. Therefore, evaluating arsenic as a noncarcinogen would be more appropriate. [Specifically, the body methylates the arsenic to form monomethyl arsenic and dimethyl arsenic. There is a limited capacity for the body to metabolize methylate arsenic, but this limit is generally reached when the body's intake of arsenic approximately exceeds 500 µg/day. Concentrations of arsenic in surface soil for potential receptors evaluated in this HHRA result in intakes that are well within the body's ability to metabolize arsenic. Although some humans may be more sensitive to arsenic, in that they are "poor methylators," the average exposure concentration for the site is more than three orders of magnitude below the normal limit of metabolic saturation and is most likely below levels that would trigger responses in sensitive individuals.]

In nature, chromium (III) predominates over chromium (VI) (Langård and Norseth 1986). Little chromium (VI) exists in biological materials, except shortly after exposure, because reduction to chromium (III) occurs rapidly. Toxicity criteria are available for two different forms of chromium, the trivalent state and the hexavalent state, the latter that is considered to be more toxic. However, Area A chromium speciation was not available for sampled media. Therefore, it was conservatively assumed that chromium is present in the hexavalent form. This would tend to overestimate the noncarcinogenic risks at the site.

6.7.4 Uncertainties Associated with Risk Characterization and Blood-Lead Model

Several uncertainties are associated with the risk characterization process, including the model used to assess blood-lead levels and risks. Incremental cancer risks (ICRs) and HIs are summed for all potential COPCs and for all applicable routes of exposure. Summing the risks implies that no antagonistic or synergistic effects exist between chemicals. It also assumes that similar mechanisms of action and metabolism are prevalent. Therefore, the use of this approach may either underestimate or overestimate the risks, depending on the chemical-specific interactions, which cannot be predicted. The direction of the uncertainty cannot be defined, but the methodology used is based on current EPA guidance.

Risks to any individual may also be overestimated by summing multiple assumed exposure pathway risks for any single receptor. Although every effort was made to develop reasonable scenarios, not all individual receptors may be exposed via all pathways considered.

The blood-lead model accounts for the multimedia nature of lead exposure, incorporates absorption and pharmacokinetic information, and allows the risk manager to consider the potential distributions of exposure and risk likely to occur at a site (the model goes beyond providing a single point estimate output). Although uncertainties are associated with blood-lead modeling, these uncertainties are considered lower than those that conceivably would result from similar lead evaluations performed using a traditional toxicity slope-based approach.

Several uncertainties and limitations in the use of the blood-lead model are relevant to the human health risk assessment. The model uses a default of 30 percent lead absorption from soil. However, the bioavailability of lead from different sources may be variable due to differences in lead speciation, particle size, and mineral matrix and may also vary as a function of physiological parameters such as age, nutritional status, gastric pH, and transit time. For example, lead absorption from paint chips in soil may be different than lead absorption from other chemical forms.

Also, blood-lead variability in the model is characterized by a single number, the geometric standard deviation, which is set to a default value of 1.6. This value represents the aggregate uncertainty in all sources of population variability, including biological, uptake, exposure, sampling, and analytical components. Child blood-lead level predictions reflect only the contributions of sources entered into the model and do not take into account any existing body burden that may be the result of prior exposures or any exposures that may have taken place at alternate locations away from the household or neighborhood level, such as parks or daycare centers.

6.8 AREA A ECOLOGICAL RISK EVALUATION

Ecological receptors on- or off-base, such as aquatic and semi-aquatic biota, may be at risk from contaminants released from Area A, specifically Sites 2 and 3. Accordingly, a screening-level ecological risk assessment (ERA) was performed to characterize the potential risks from site-related contaminants to ecological receptors that inhabit the installation area. The ERA was conducted for Area A in accordance with EPA guidance (EPA, 1994a, 1994b). Representative exposure point contaminant concentrations in surface water and sediment were compared to benchmark toxicity values (BTVs) that are protective of ecological receptors near the site. Potential risks to ecological receptors were investigated in the form of environmental effects quotients (EEQ) values, which are the ratio of the representative contaminant concentration to the BTV. EEQ values were summed in each medium at each site to generate environmental effects index (EEI) values. Risks were considered possible when an EEQ or EEI value was greater than 1, but other quantitative and qualitative factors were investigated to more fully assess potential risks

6.8.1 ERA Approach

This section provides an outline of the general approach that was taken to assess the impacts of site contamination on ecological receptors and the habitats that support these organisms. This assessment generally followed a two-step process, as follows:

Step 1: Preliminary Problem Formulation and Ecological Effects Characterization

- Preliminary Problem Formulation (Section 6.8.2) - This is the first phase of an ERA, which discusses the goals, breadth, and focus of the assessment. It includes general descriptions of NAWC Warminster RI areas with emphasis on the habitats and ecological receptors present. This phase also involves characterization of contaminant sources and migration routes, evaluation of routes of contaminant exposure, and selection of ecological contaminants of potential concern (COCs). Assessment and measurement endpoints that will be evaluated are also selected. Finally, a conceptual model is developed that describes how contaminants associated with Area A may come into contact with ecological receptors.

- Ecological Effects Characterization (Section 6.8.3) - In this component, medium-specific ecological benchmarks for each COC (i.e., concentrations of each contaminant above which adverse effects to ecological receptors may occur) are identified. This step is undertaken concurrently with the exposure assessment described below.

Step 2: Preliminary Exposure Assessment and Risk Characterization

- Preliminary Exposure Assessment (Section 6.8.3) - This portion of the ERA includes the identification of the data used to represent concentrations of contaminants to which ecological receptors may be exposed in various media and the actual selection of exposure point contaminant concentrations from those data.

- Risk Characterization (Section 6.8.4) - In this step, exposure point concentrations are compared to benchmarks in order to characterize potential risk to ecological receptors of concern from contaminant exposure. COPCs found to pose potential risk after these comparisons are placed on a list of ecological contaminants of concern.

When these two steps are completed, the results can be interpreted and the uncertainties associated with the ERA can be addressed (Section 6.8.5). The above process, described in further detail below, represents the general ERA approach and is a summation of EPA Region III BTAG-recommended ERA guidelines (EPA, 1994b), which served as the basis for the ERA methodology (Figure 6-2). Furthermore,

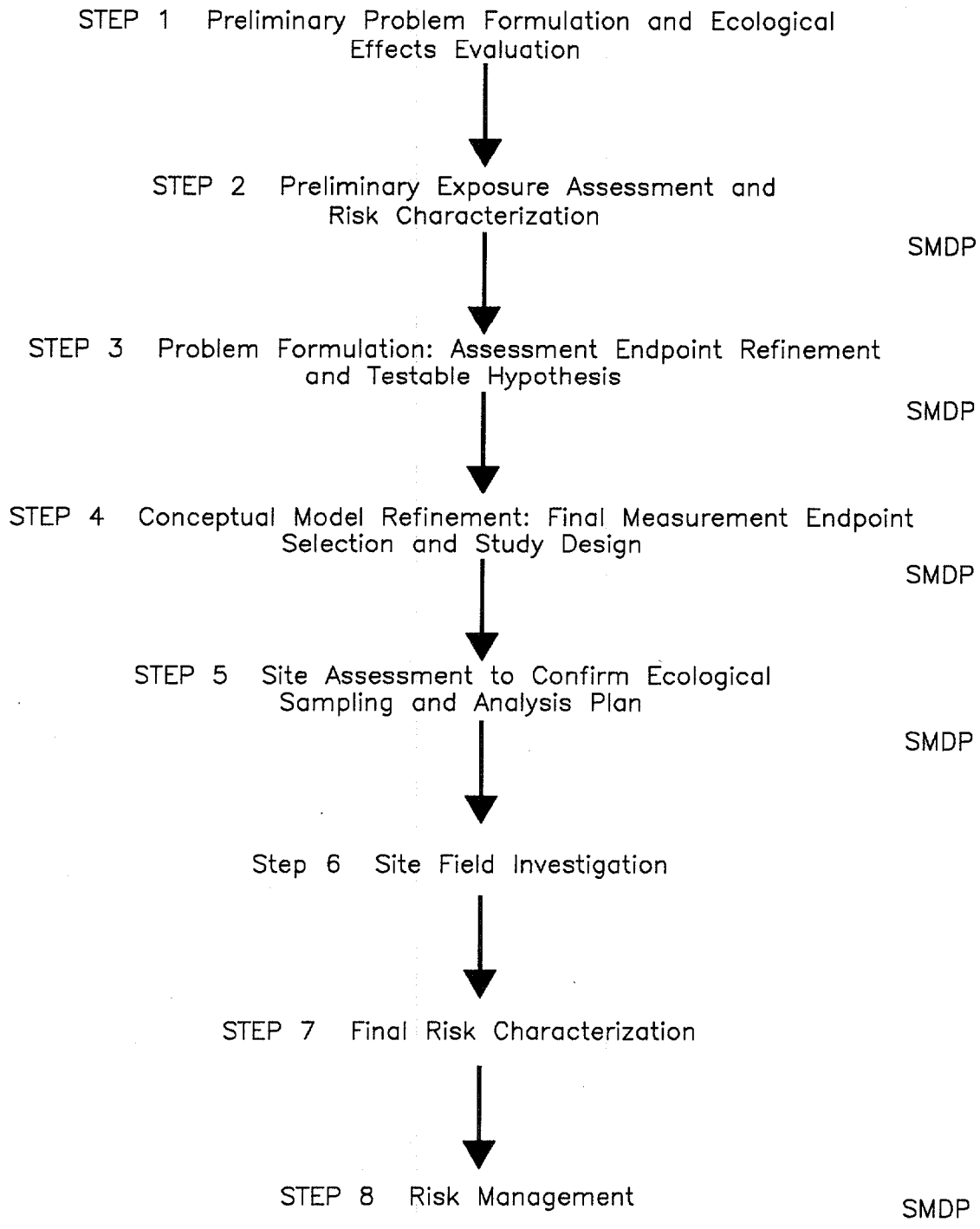
the ERA was conducted in accordance with other available ERA guidance documents (EPA, 1992; Wentsel et al., 1994) and recent publications (Suter, 1993; Calabrese and Baldwin, 1993). Due to the potential complexity of ERAs, they are often conducted using a tiered approach and punctuated with scientific/management decision points (SMDPs; Figure 6-1), which are meetings involving the risk assessors, risk managers, and client to control costs, prevent unnecessary analyses, and ensure that the ERA is proceeding in an efficient, timely manner. Information analyzed in one tier is evaluated to determine whether the objectives of the study have been met and then may be used to identify the data required for the next tier, if necessary. This ERA can be considered a "screening-level" assessment, or "Tier 1" assessment, since it is based on only a conservative initial screening of contaminant concentrations against contaminant-specific benchmarks (EPA, 1994b). Tier 2 and Tier 3 assessments, referred to as "semi-quantitative" and "quantitative" assessments, respectively, are more focused studies that incorporate the initial screening but also encompass detailed laboratory and field studies or extensive modeling (EPA, 1994b). The same process summarized above was used to assess potential ecological risks for Site 5.

6.8.2 Preliminary Problem Formulation

Area A is located along a headwater tributary of Little Neshaminy Creek on the west side of Jacksonville Road and to the north of the main building complex at NAWC Warminster (Figure 4-4). Surface water runoff from suspected sources within Area A enters the tributary, and groundwater flow patterns indicate that minor amounts of localized perched water within the unsaturated zone may discharge to the tributary. The tributary originates from a stormwater outfall under Jacksonville Road. Surface water drainage from portions of the NAWC airfield discharges from this culvert.

Sites 2 and 3 extend along a channeled portion of the stream approximately 600 feet downstream from the road/culvert. Area A itself contains no significant terrestrial habitat, and therefore, the focus of this assessment is limited to the tributary and to those riparian areas adjacent to (i.e., within approximately 50 feet of) the stream bank.

The unnamed tributary is the focus of the Area A ecological risk assessment. Therefore, many terrestrial exposure routes were not applicable. However, terrestrial receptors may come into contact with contaminants in surface water by using it for drinking water, although this exposure route represents a negligible portion of total exposure for most receptors. Aquatic and semi-aquatic organisms inhabiting the unnamed tributary of Neshaminy Creek and the surrounding riparian habitats may be exposed to contaminants via direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. Aquatic and semi-aquatic organisms may also be exposed to constituents from contaminated groundwater that flows into surface water in the tributary. However, potential risks to semi-aquatic receptors were investigated only qualitatively.



SMDP – Scientific/Management Decision Point

DRAWN BY EEH DATE 3/7/00	Tetra Tech NUS, Inc.	STEPS IN THE ECOLOGICAL RISK ASSESSMENT PROCESS AREA A FORMER NAWC WARMINSTER WARMINSTER, PENNSYLVANIA	CONTRACT NO. 7603
CHECKED BY DATE			OWNER NO. 0601
REVISED BY DATE			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 6–2 REV.

EEH 3/7/00 AREA-A_OU-6\7603pf01.dwg

AREA-A_OU-6\7603pf01.dwg

As discussed in Section 1.8, the Navy is conducting a long-term monitoring program for the Area A stream. Two quarterly rounds of sampling and analysis were performed in September 1999 and November 1999 (Tetra Tech NUS, 1999b). The results from this monitoring have not been included in this RI report.

6.8.2.1 Description of Ecological Setting and COPCs

The urban headwater reach of the unnamed tributary is small (average width 4 feet, average depth 5 inches) but appears to be perennial. The tributary flows to the northwest and contains pool-type areas located near the Jacksonville Road culvert and at the opposite end of the reach where the tributary exits NAWC Warminster property through a concrete pipe. The channeled segment, which is located on the installation property, has a high (10 to 12 feet) and steeply-sloped (4:1 to 5:1) south bank which leads up to a paved driveway and parking area near Site 2, and to a gravel parking area in the vicinity of Site 3.

The south bank of the stream is sparsely vegetated with various wildflowers, vines, and shrubs, including goldenrod (*Solidago* sp.), greenbriar (*Smilax* sp.) and blackberry (*Rubus* sp.). The north bank of this stream reach is more gradually-sloped and is vegetated with similar herbaceous plants and shrubs. A small forested wetland dominated by mature red-maple (*Acer rubrum*) and arrowwood (*Viburnum dentatum*) exists just to the north of the tributary and beyond the fence-line delineating the base property boundary.

During the biological characterization, an orange-colored flocculent, presumed to be oxidized iron precipitate, was observed in certain sections of the channeled stream reach. A relatively small amount of epilithic and filamentous algae was covered with the orange material, as were nearby sediments. Substrates in this stream reach are sands and small gravel, and fine sediments (i.e., silts) have accumulated in each of the pools.

Snails (Physidae) and earthworms (Oligochaeta) were observed in this part of the stream. Larval insect families (e.g., midges, mayflies) were not collected during the characterization. Small fish, believed to be creek chubs (*Semotilus atromaculatus*), were observed in the pool near Jacksonville Road but were not seen in the pool at the opposite end of the Area A. Leopard frogs (*Rana spenocephala*) were observed along the edge of the stream. No turtles or snakes were observed, but they are believed to inhabit the riparian zone of the stream and adjacent wetland. Songbirds including sparrows (*Spizella* sp.), red-winged black birds (*Agelaius phoeniceus*), and goldfinches (*Carduelis tristis*) were common in shrubs and trees near the edge of the stream. During investigations at a later date, a nesting female duck (species unknown) was also observed along the edge of the stream. Raccoon (*Procyon lotor*) tracks were observed on a sand bar in the stream. No rare, threatened, or endangered species are known to occur on or near Area A (TNC, 1992).

The major contaminant sources near Area A affecting ecological receptors include at least four general waste disposal locations. Precipitation runoff or stormwater outfalls from these sites may carry constituents

to nearby surface waters and sediments in the unnamed tributary. Also, infiltrating precipitation may cause the contamination of subsurface soil and groundwater at Area A. Groundwater from the site may eventually discharge to surface water in the tributary; contaminants may be subsequently deposited in sediment or they may accumulate in the tissues of aquatic organisms.

Since most of Area A and the surrounding area is composed of asphalt, roadways, or mowed grass, no significant terrestrial habitat is present. Hence, drainage pathways and the unnamed tributary of Little Neshaminy Creek are the focus of the assessment and many terrestrial exposure routes were not applicable. However, terrestrial receptors may come into contact with contaminants in surface water by using it for drinking water, although this exposure route represents a negligible portion of total exposure for most receptors. Aquatic and semi-aquatic organisms inhabiting the creek and the surrounding riparian habitats may be exposed to contaminants via direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. However, potential risks to semi-aquatic receptors were investigated only qualitatively.

COCs were all contaminants detected during RI surface water and sediment sampling within Area B. Calcium, magnesium, potassium, and sodium were excluded as COCs in all media since they are essential nutrients that are toxic only in extremely high concentrations. Also, contaminants that were detected in 5 percent or less of the samples in a given medium at each area were excluded as COCs.

Descriptions of habitat types and ecological receptors downgradient from Area A are presented in Section 3.6. These encompass both aquatic and terrestrial habitats, although aquatic habitats were the only habitats quantitatively assessed in this ERA. Wetlands on and near the installation were assessed in 1994 (HNUS, 1994c), and the results were incorporated into Section 3.6. Data from a base species inventory were also utilized in this ERA (TNC, 1992), as are the results of biological characterizations conducted at the base during 1990 media sampling for this study. An evaluation of threatened and endangered species on and around the three areas was also provided, in accordance with Endangered Species Act (ESA) requirements. ARARs pertinent to this assessment are listed below:

- Executive Order 11988, Protection of Floodplains.
- Executive Order 11990, Protection of Wetlands.
- Clean Water Act (Section 404 40 CFR 230.10).
- Migratory Bird Treaty Act (16 USC 703 et seq.).
- Fish and Wildlife Coordination Act (16 USC 661 et seq.)
- Endangered Species Act (16 USC 1531 et seq.).
- Federal Water Quality Criteria.

6.8.2.2 Potential Release Pathways and Exposure Routes

Aquatic and semi-aquatic organisms inhabiting the study may be exposed to contaminants via direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. Aquatic and semi-aquatic organisms may also be exposed to constituents from contaminated groundwater that flows into surface water.

To select ecological COPCs, an initial screen of the RI surface water and sediment sample results was performed. Calcium, magnesium, potassium, and sodium were excluded as COPCs in all media since they are essential nutrients that are toxic only in extremely high concentrations. Also, contaminants that were detected in 5 percent or less of the samples collected in a given medium at each area were initially excluded as COPCs.

6.8.2.3 Measurement Endpoints and Ecological Risk Model

As discussed in EPA (1994a) and Wentsel et al. (1994), one of the major tasks in problem formulation is the selection of assessment and measurement endpoints. An assessment endpoint is defined as "an explicit expression of actual environmental values that are to be protected" (EPA, 1994a). Measurement endpoints are "measurable ecological characteristics that are related to the valued characteristic chosen as the assessment endpoint" (EPA, 1994a). For this ERA, the most appropriate assessment endpoint was the maintenance of aquatic receptor populations. Therefore, the specific objectives of this assessment were to determine if exposure to contaminants present in the surface water and sediments near Site 5 is likely to result in declines in ecological receptor populations. Declines in populations could result in a shift in community structure and possible elimination of resident species from aquatic environments.

As indicated above, measurement endpoints are related to assessment endpoints, but these endpoints are more easily quantified or observed. In essence, measurement endpoints serve as surrogates for assessment endpoints. While declines in populations and shifts in community structure can be quantified, studies of this nature are generally time consuming and difficult to interpret. However, measurement endpoints indicative of observed adverse effects on individuals are relatively easy to measure in toxicity studies and can be related to the assessment endpoint. For example, contaminant concentrations that lead to decreased reproductive success or increased mortality of individuals in toxicity tests could, if found in the environment, result in shifts in population structure, potentially altering the community composition associated with the three areas investigated in this ERA.

For surface water, the measurement endpoints will be contaminant concentrations in surface water associated with adverse effects on growth, survival, and reproduction of aquatic organisms (surface water benchmark values). For sediments, the measurement endpoints will be contaminant concentrations in

sediment associated with adverse effects on growth, survival, and reproduction of benthic organisms (sediment benchmark values).

Semi-aquatic receptors, such as piscivorous mammals, may also be exposed to aquatic contaminants. However, the investigation of potential risks to those receptors is more complex and is beyond the scope of this initial screening. Nonetheless, the determination of potential risks to aquatic receptors, as reflected in the measurement endpoints described above, may indirectly indicate potential risks to semi-aquatic receptors. For example, potential risks to aquatic receptors from bioaccumulatable contaminants may indicate potential risk to semi-aquatic receptors that feed on them. Therefore, endpoints and potential risks for semi-aquatic receptors will be qualitatively assessed in this ERA.

A conceptual ecological risk model was formatted to identify potentially exposed receptor populations and applicable exposure pathways, based on the physical nature of the site and the potential contaminant source areas. Actual or potential exposures of ecological receptors associated with Area A were determined by identifying the most likely pathways of contaminant release and transport. A complete exposure pathway has three components: a source of contaminants that can be released to the environment, a route of contaminant transport through an environmental medium, and an exposure or contact point for an ecological receptor. The conceptual ecological model for the site is presented in Figure 6-3.

6.8.3 Ecological Effects Characterization

For this ERA, ecologically based benchmark toxicity values (BTVs or "benchmarks"), concentrations of contaminants in various media protective of ecological receptors, were selected to screen exposure point concentrations of COPCs in surface water and sediment to determine if they should be retained as COPCs. Methods used for the selection of media-specific benchmarks used in this ERA are provided below.

Actual exposures of aquatic receptors to COPCs were assumed to be primarily chronic (long-term) exposures, usually at sublethal concentrations. For this ERA, benchmark values used to identify surface water COCs were chronic screening values, primarily federal AWQCs presented as EPA Region III BTAG screening levels (EPA, 1995) or in 40 CFR Part 131, March 4, 1995. AWQCs are ARARs and are protective of a wide variety of sensitive species. Site-specific surface water benchmarks were calculated from AWQCs using a site-specific water hardness of 115 mg/L for several inorganic contaminants, as recommended by EPA (1996). In addition, both dissolved and total metals in surface water were assessed at each area, using appropriate BTVs described above. Dissolved metals are the more bioavailable, and therefore the more toxic, form of metals in surface water. Surface water benchmarks used in this ERA and their sources are presented in area-specific ERA data summary tables.

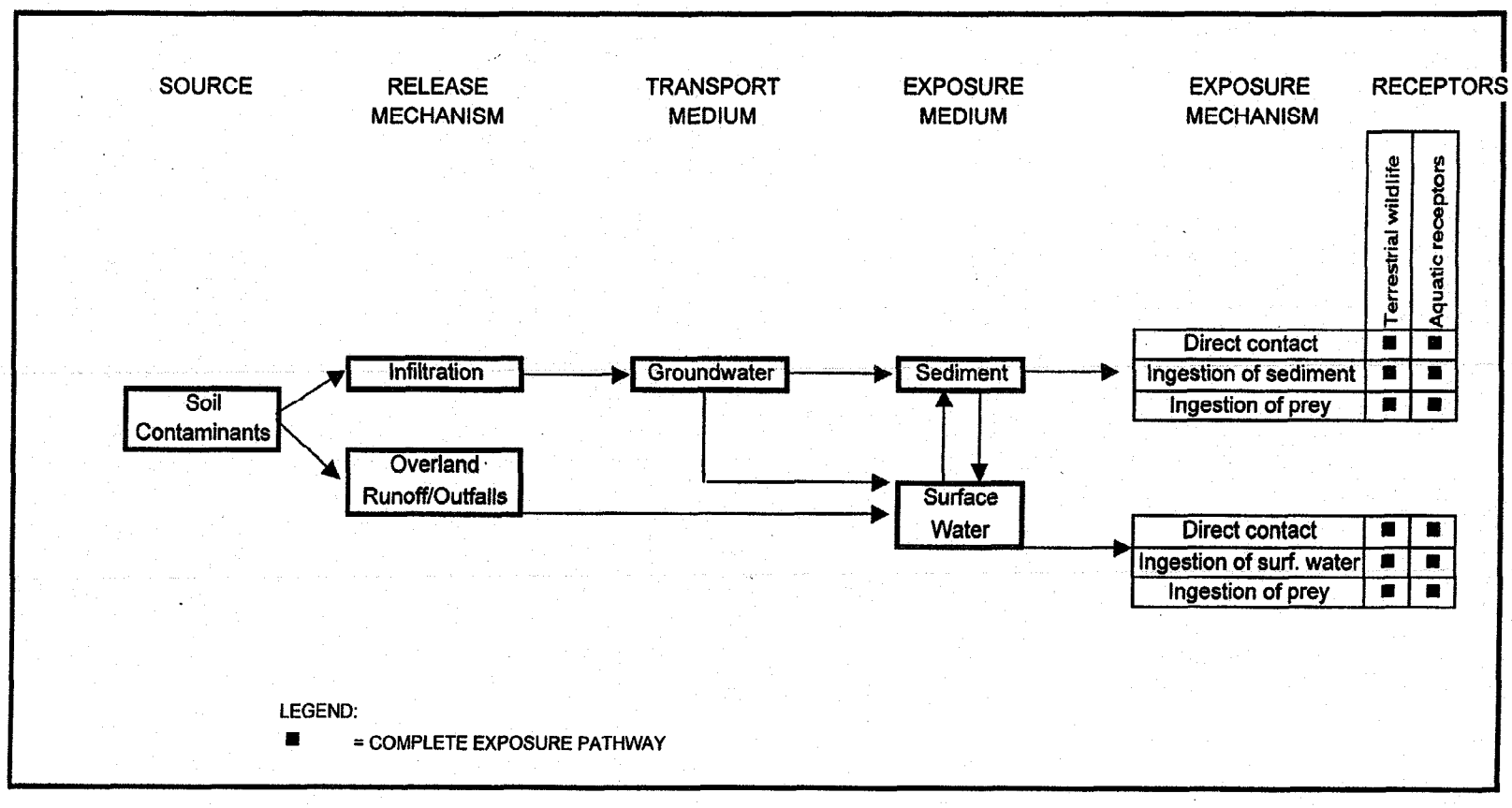


FIGURE 6-3
CONCEPTUAL SITE MODEL - ECOLOGICAL RISK ASSESSMENT
AREA A STREAM
NAWC WARMINSTER, PENNSYLVANIA

BTVs for sediment-dwelling organisms were gathered from the most widely accepted guidance. EPA Region III BTAG screening levels were preferentially used; these are primarily Effects Range-Low values from NOAA (Long et al., 1995; Long and Morgan, 1991). When values were not available from these sources, BTVs were obtained from most recent EPA guidance (1996), which includes EPA sediment quality criteria (SQC) and EPA sediment quality benchmarks (SQB) calculated using equilibrium partitioning methods. Other sources include Wisconsin DNR BTVs (1985, 1990), Washington Department of Ecology BTVs (1991), and the Ontario Ministry of the Environment sediment guidelines (MOE, 1993). Sediment benchmarks used in this assessment are summarized in area-specific ERA data summary tables. Although total organic carbon (TOC) data were available, the calculation of site-specific sediment benchmarks using TOC was beyond the scope of this initial screening. However, site-specific TOC data and their relation to sediment toxicity at each site are discussed qualitatively in area-specific sections, along with sediment grain size data.

For this ERA, ecologically-based benchmark toxicity values (BTVs) were selected to screen exposure point concentrations of COCs in surface water and sediment to determine if they should be retained as COCs. BTVs used for the Area A ERA are presented in Tables 6-53 through 6-56.

6.8.4 Preliminary Exposure Assessment

Data used to obtain exposure point contaminant concentrations in environmental media used for this ERA were those generated during RI sampling activities. The maximum detected contaminant concentrations or the 95 percent UCL were used as exposure point concentrations in surface water and sediment, in accordance with EPA Region III BTAG guidelines for data usage in ERAs (1994b). Since most of the 95 percent UCL values were less than 80 percent of the maximum detected value, the maximum was used in almost all cases, as recommended by EPA Region III BTAG (1994b). Background data are presented for comparative purposes and were obtained from facility-wide background sampling. Detailed descriptions of sampling locations, data validation, data treatment, and data selection were presented in previous sections. Site-specific sampling data for streams or drainage pathways near Area A are summarized in Sections 4.6 and 4.7.

6.8.5 Risk Characterization

As identified by EPA (1994a), the second step in the ecological risk assessment process compares exposure point contaminant concentrations with benchmark concentrations protective of ecological receptors. Once this step was completed for this study, the results were reviewed to determine whether little or no ecological risk is associated with activities on the installation or additional information must be generated to verify that ecological receptors are at risk. The ratio of the exposure point contaminant

TABLE 6-53
DATA SUMMARY FOR SURFACE WATER ORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(µg/l)

CONTAMINANT OF POTENTIAL CONCERN	BACKGROUND		SITE-RELATED			BENCHMARK (µg/l) (1)
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	EXPOSURE CONCENTRATION	
Volatile Organic Chemicals						
BENZENE	NOT DETECTED	-	1 / 13	0.2	0.2	530 (2)
BROMOMETHANE	NOT DETECTED	-	1 / 13	0.5	0.5	NA
2-BUTANONE	NOT DETECTED	-	1 / 11	4	4	322000 (3)
CARBON DISULFIDE	NOT DETECTED	-	1 / 13	6	6	NA
CHLOROETHANE	NOT DETECTED	-	1 / 13	3	3	NA
CHLOROMETHANE	NOT DETECTED	-	1 / 13	4	4	NA
1,1-DICHLOROETHANE	NOT DETECTED	-	1 / 13	0.95	0.95	20000 (4)
TETRACHLOROETHENE	NOT DETECTED	-	1 / 13	1	1	840 (5)
TRICHLOROETHENE	NOT DETECTED	-	3 / 13	1 - 2	2	21900 (5)
Semivolatile Organic Chemicals						
BENZ(A)ANTHRACENE	NOT DETECTED	-	1 / 8	0.1	0.1	6.3 (6)
BENZO(B)FLUORANTHENE	NOT DETECTED	-	1 / 8	0.2	0.2	30 (7)
CHRYSENE	NOT DETECTED	-	1 / 8	0.2	0.2	30 (7)
DI-N-OCTYLPHTHALATE	NOT DETECTED	-	2 / 6	0.1 - 0.2	0.2	0.3 (6)
DIETHYLPHTHALATE	NOT DETECTED	-	1 / 6	0.2	0.2	3 (6)
FLUORANTHENE	NOT DETECTED	-	1 / 8	0.3	0.3	398(2)
PYRENE	NOT DETECTED	-	1 / 8	0.3	0.3	30 (7)
Semivolatile Organic Chemicals						
4,4'-DDD	NOT DETECTED	-	1 / 9	0.0092	0.0092	0.06(3)
4,4'-DDT	NOT DETECTED	-	1 / 7	0.014	0.014	0.001(6)

NA = Benchmark not available.

1: Benchmarks are for freshwater and represent Ambient Water Quality Criteria (USEPA, 1991, Water Quality Criteria Summary Concentrations, dated May 1), unless otherwise indicated.

2: Corresponds to acute LOEL/10 (USEPA, 1991).

3: Region III BTAG acute screening level (August 9, 1995): acute screening level/10.

4: Chronic Ambient Water Quality Criteria (USEPA, 1991) for 1,2-Dichloroethane.

5: Corresponds to chronic LOEL value (USEPA, 1991).

6: Region III BTAG chronic screening level (August 9,1995).

7: Region III BTAG acute marine screening level (August 9, 1995): acute screening level/10.

TABLE 6-54

DATA SUMMARY FOR SURFACE WATER INORGANICS (TOTAL METALS) - AREA A

NAWC WARMINSTER, PENNSYLVANIA

(µg/l)

CONTAMINANT OF POTENTIAL CONCERN	BACKGROUND		SITE-RELATED			BENCHMARK (µg/l)* (1)
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	EXPOSURE CONCENTRATION	
BARIUM	2 / 3	60 - 69.7	16 / 18	59.5 - 172	172	1000 (2)
CADMIUM	1 / 4	4	1 / 16	2.5	2.5	1.15
CHROMIUM (TOTAL)	NOT DETECTED	-	1 / 14	4	4	199.59
COPPER	NOT DETECTED	-	4 / 8	5.6 - 106	106	12.79
LEAD	NOT DETECTED	-	5 / 15	2.9 - 28.5	28.5	3.01
MANGANESE	3 / 3	11.5 - 83	15 / 16	15.1 - 486	486	14500 (3)
NICKEL	NOT DETECTED	-	3 / 18	12.5 - 82.75	82.75	176.92
THALLIUM	NOT DETECTED	-	1 / 15	2	2	40 (4)
ZINC	NOT DETECTED	-	14 / 15	20.8 - 117	117	117.65

* = Based on site-specific hardness value (115 mg CaCO3/l) for hardness-dependent metals: cadmium, chromium (calculation assuming chromium III), copper, lead, nickel, and zinc.

1: Benchmarks are for freshwater and represent Ambient Water Quality Criteria (USEPA, 1995. 40 CFR Part 131, Revision of Metals Criteria, dated May 4), unless otherwise indicated.

2: Region III BTAG acute screening level (August 9, 1995): acute screening level/10.

3: Region III BTAG chronic screening level (August 9, 1995).

TABLE 6-55 (PAGE 1 OF 2)

DATA SUMMARY FOR SEDIMENT ORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(µg/kg)

CONTAMINANT OF POTENTIAL CONCERN	BACKGROUND		SITE-RELATED			BENCHMARK (µg/kg) (1)
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	EXPOSURE CONCENTRATION	
Volatile Organic Chemicals						
ACETONE	NOT DETECTED	-	1 / 11	108	108	NA
CARBON TETRACHLORIDE	NOT DETECTED	-	1 / 25	28	28	NAP
CHLOROFORM	NOT DETECTED	-	2 / 25	4 - 14.75	14.75	6300 (2)
CHLOROMETHANE	NOT DETECTED	-	1 / 25	21	21	NAP
1,1-DICHLOROETHENE	NOT DETECTED	-	1 / 25	3	3	NAP
1, 2-DICHLOROETHENE (TOTAL	NOT DETECTED	-	6 / 25	2 - 22	22	NA
ETHYLBENZENE	NOT DETECTED	-	1 / 25	4	4	NAP
TETRACHLOROETHENE	NOT DETECTED	-	9 / 24	2 - 130	130	57 (AET) (3)
2-BUTANONE	1 / 3	9	3 / 23	3 - 45	45	NA
TOLUENE	1 / 4	4	1 / 24	82	82	NAP
1,1,1-TRICHLOROETHANE	NOT DETECTED	-	1 / 25	2	2	NAP
TRICHLOROETHENE	NOT DETECTED	-	12 / 25	2 - 1300	1300	1600 (7)
XYLENE (TOTAL)	NOT DETECTED	-	1 / 13	19	19	NA
Semivolatile Organic Chemicals						
ACENAPHTHENE	NOT DETECTED	-	12 / 19	44 - 3500	3500	16 (ER-L) (5)
ACENAPHTHYLENE	NOT DETECTED	-	4 / 19	100 - 270	270	44 (ER-L) (5)
ANTHRACENE	2 / 3	95 - 97	19 / 19	82 - 8300	8300	85.3 (ER-L) (5)
BENZ(A)ANTHRACENE	3 / 3	210 - 380	19 / 19	390 - 20000	20000	261 (ER-L) (5)
BENZO(A)PYRENE	2 / 3	260 - 560	19 / 19	360 - 17000	17000	430 (ER-L) (5)
BENZO(B)FLUORANTHENE	2 / 3	320 - 830	19 / 19	540 - 25000	25000	3200 (AET) (5)
BENZO(G,H,I)PERYLENE	2 / 3	150 - 370	19 / 19	290 - 13000	13000	670 (AET) (5)
BENZO(K)FLUORANTHENE	2 / 3	200 - 290	19 / 19	210 - 20000	20000	3200 (AET) (3)
BIS(2-ETHYLHEXYL)PHTHALATE	NOT DETECTED	-	15 / 15	210 - 7900	7900	1300 (AET) (3)
BUTYLBENZYLPHTHALATE	NOT DETECTED	-	4 / 18	41 - 380	380	63 (AET) (3)
CARBAZOLE	1 / 2	240	17 / 17	61 - 5700	5700	NA
CHRYSENE	3 / 3	190 - 590	19 / 19	390 - 24000	24000	384 (ER-L) (5)
DI-N-BUTYLPHTHALATE	1 / 1	59	2 / 12	50 - 310	310	6200 (5)
DI-N-OCTYLPHTHALATE	NOT DETECTED	-	2 / 7	765 - 860	860	6200 (AET) (5)
DIBENZ(A,H)ANTHRACENE	1 / 3	53	10 / 19	130 - 5300	5300	63.4 (ER-L) (5)
DIBENZOFURAN	NOT DETECTED	-	9 / 19	52 - 2400	2400	540 (AET) (3)
FLUORANTHENE	3 / 3	380 - 1400	19 / 19	940 - 43000	43000	600 (ER-L) (5)
FLUORENE	1 / 3	47	15 / 19	83 - 5900	5900	19 (ER-L) (5)
INDENO(1,2,3-CD)PYRENE	2 / 3	190 - 320	19 / 19	240 - 14000	14000	600 (AET) (5)
2-METHYLNAPTHALENE	NOT DETECTED	-	1 / 7	320	320	70 (ER-L) (5)
4-METHYLPHENOL	1 / 3	200	2 / 19	420 - 1400	1400	670 (AET) (3)
NAPHTHALENE	NOT DETECTED	-	2 / 19	60 - 530	530	160 (ER-L) (5)
PYRENE	3 / 3	330 - 760	19 / 19	680 - 40000	40000	665 (ER-L) (5)

TABLE 6-55 (PAGE 2 OF 2)

DATA SUMMARY FOR SEDIMENT ORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(µg/kg)

CONTAMINANT OF POTENTIAL CONCERN	BACKGROUND		SITE-RELATED			BENCHMARK (µg/kg) (1)
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	EXPOSURE CONCENTRATION	
Pesticides and PCBs						
4,4'-DDD	NOT DETECTED	-	15 / 20	4.5 - 130	130	<16 (AET) (5)
4,4'-DDE	NOT DETECTED	-	2 / 21	7 - 12.6	12.6	2.2 (ER-L) (5)
4,4'-DDT	1 / 2	4.9	15 / 18	8.6 - 600	600	1 (ER-L) (4)
ALDRIN	NOT DETECTED	-	5 / 21	2.1 - 78.5	78.5	100 (5)
ALPHA-CHLORDANE	NOT DETECTED	-	2 / 19	2.2 - 2.7	2.7	100 (5)
AROCLOR-1016	NOT DETECTED	-	1 / 21	110	110	NAP
AROCLOR-1248	NOT DETECTED	-	1 / 21	1500	1500	NAP
AROCLOR-1254	1 / 3	24	13 / 21	20 - 615	615	5 (LEL) (6)
AROCLOR-1260	NOT DETECTED	-	3 / 21	160 - 1500	1500	5 (LEL) (6)
DELTA-BHC	NOT DETECTED	-	2 / 21	2.2 - 3.2	3.2	100 (5)
DIELDRIN	NOT DETECTED	-	1 / 21	4.8	4.8	NAP
ENDOSULFAN II	NOT DETECTED	-	5 / 21	3.8 - 11	11	5.4 (7)
ENDOSULFAN SULFATE	NOT DETECTED	-	1 / 21	8.8	8.8	NAP
ENDRIN	1 / 3	5.5	13 / 21	6 - 48	48	100 (5)
ENDRIN ALDEHYDE	NOT DETECTED	-	3 / 18	12 - 44	44	100 (5)
ENDRIN KETONE	NOT DETECTED	-	2 / 21	7.9 - 10	10	100 (5)
GAMMA-CHLORDANE	NOT DETECTED	-	8 / 19	0.98 - 7.1	7.1	100 (5)

NAP = Not applicable since frequency of detection is <5%

NA = Benchmark not available.

AET = Apparent Effects Threshold Value as developed for Puget Sound, State of Washington.

ER-L = Effects Range-Low; value from data based on studies conducted primarily on coastal marine and estuarine environments.

LEL = Lowest Effect Level; level of contamination tolerated by the majority of benthic organisms.

1: Benchmarks are for freshwater sediments, unless otherwise indicated.

2: Wisconsin Department of Natural Resources (1985, 1990), Criteria for Sediments from Great Lakes harbors for disposal in water, in: Washington Department of Ecology, 1991, Summary of Criteria and Guidelines for Contaminated Freshwater Sediments; value calculated for sediments containing 5% of total organic carbon (TOC).

3: NOAA, 1994. NOAA Screening Guidelines for Organics and Inorganics, Quick Reference Cards, HAZMAT REPORT 94-8.

4: Long and Morgan, 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical memorandum NOS OMA 52 (August).

5: Region III BTAG screening level (August 9, 1995).

6: MOE, 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, Ministry of Environment and Energy, Ontario, Canada (August).

7: USEPA (1996)

TABLE 6-56
DATA SUMMARY FOR SEDIMENT INORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(mg/kg)

CONTAMINANT OF POTENTIAL CONCERN	BACKGROUND		SITE-RELATED			BENCHMARK (mg/kg) (1)
	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	FREQUENCY OF DETECTION	RANGE OF POSITIVE DETECTION	EXPOSURE CONCENTRATION	
ARSENIC	2 / 2	2.3 - 2.8	25 / 25	2 - 14.1	14.1	8.2 (ER-L) (2)
BARIUM	3 / 4	31.4 - 65.4	25 / 26	62.7 - 1060	1060	500 (3)
BERYLLIUM	3 / 3	0.52 - 0.62	25 / 25	0.5 - 2.1	2.1	NA
CADMIUM	NOT DETECTED	-	7 / 9	0.2 - 8.4	8.4	1.2 (ER-L) (4)
CHROMIUM (TOTAL)	4 / 4	7.7 - 11.7	27 / 27	13.7 - 224	224	26 (LEL) (5)
COBALT	1 / 1	4.4	23 / 23	3.4 - 75.2	75.2	50 (6)
COPPER	3 / 3	5.4 - 8.2	26 / 26	13.5 - 136	136	34 (ER-L) (2)
LEAD	3 / 4	9.8 - 24.6	27 / 27	23.9 - 404	404	46.7 (ER-L) (2)
MANGANESE	4 / 4	144 - 289	27 / 27	115 - 11400	11400	460 (LEL) (5)
MERCURY	NOT DETECTED	-	16 / 27	0.09 - 2.25	2.25	0.15 (ER-L) (2)
NICKEL	3 / 3	4.4 - 6.3	27 / 27	6.3 - 224	224	20.9 (ER-L) (2)
SELENIUM	NOT DETECTED	-	4 / 27	0.15 - 1.9	1.9	1 (3)
SILVER	NOT DETECTED	-	3 / 24	0.8 - 2	2	1 (ER-L) (4)
VANADIUM	4 / 4	10.3 - 13.6	27 / 27	14.5 - 157	157	NA
ZINC	5 / 5	32.9 - 6180	26 / 26	61 - 8435	8435	150 (ER-L) (2)

NA = Benchmark not available.
ER-L = Effects Range-Low; value from data based on studies conducted primarily on coastal marine and estuarine environments.
LEL = Lowest Effect Level; level of contamination tolerated by the majority of benthic organisms.
1: Benchmarks are for freshwater sediments, unless otherwise indicated.
2: Region III BTAG screening level (August 9, 1995).
3: Wisconsin Department of Natural Resources (1985, 1990), Criteria for Sediments from Great Lakes harbors for disposal in water, in: Washington Department of Ecology, 1991, Summary of Criteria and Guidelines for Contamina
4: NOAA, 1994. NOAA Screening Guidelines for Organics and Inorganics, Quick Reference Cards, HAZMAT REPORT 94-8.
5: MOE, 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, Ministry of Environment and Energy, Ontario, Canada (August).
6: Open Water Disposal Guideline, in: MOE, 1993 (see footnote 5).

concentration to the benchmark value is called the Ecological Effects Quotient (EEQ) and is defined as follows:

$$EEQ_i = EPC_i/BTV_i$$

where: EEQ_i = Ecological Effects Quotient for COPC "i" (unitless)

EPC_i = Exposure Point Concentration for COPC "i" (ug/l or mg/kg)

BTV_i = Benchmark Toxicity Value for COPC "i" (ug/l or mg/kg)

When the ratio of the exposure point concentration to its respective benchmark value exceeded 1.0, adverse impacts were considered possible and the COPC was retained. The EEQ value should not be construed as being probabilistic; rather, it is a numerical indicator of the extent to which an exposure point concentration exceeds or is less than a benchmark. When EEQ values exceed 1.0, it is an indication that ecological receptors are potentially at risk; additional evaluation or data may be necessary to confirm with greater certainty whether ecological receptors are actually at risk, especially since most benchmarks are conservatively derived. Furthermore, other factors, such as low frequency of detection, may mitigate potential risks for a COC with an elevated EEQ value. As a result of the conservatism inherent in most benchmark derivation, EPA Region III (1994) has suggested that EEQs greater than one are indicative of low to moderate potential risk; EEQs greater than 10 are indicative of moderate potential risk; and EEQs greater than 100 are indicative of high potential risk.

The use of EEQs is probably the most common method used for risk characterization in ERAs. Advantages of this method, according to Barnthouse et al. (1986), include the following:

- The EEQ method is relatively easy to use, is generally accepted, and can be applied to any data.
- The method is useful when a large number of contaminants must be screened.

This method of risk characterization has some inherent limitations. One primary limitation is that it is a "no/maybe" method for relating toxicity to exposure. That is, it uses single values for exposure concentrations and benchmark values and does not account for the variability in both these parameters or for incremental or cumulative toxicity. To address cumulative toxicity, EEQs were summed for all contaminants in a given medium to obtain an Ecological Effects Index (EEI). Although similar to an EEQ in that an EEI value of one or greater indicates potential risk, the EEI should be interpreted with caution. The EEI value may exacerbate the preceding uncertainties in the assessment. For example, most of an EEI value may be due to a single contaminant that has a high EEQ but a low frequency of detection. Also, ecological toxicity is not necessarily additive. As mentioned above, multiple contaminants may have synergistic, and even ameliorating, effects. Different types of contaminants also have different target organs and modes of action, confounding additive effects.

The comparisons described above are presented in area-specific screening tables to select COCs in surface water and sediment in each individual area assessment section. In addition, a data summary table is presented for surface water and sediment data at each area. Data summary tables include the frequency of detection for each COPC, as well as the range of detections, exposure point concentration, and, as mentioned earlier, contaminant-specific benchmarks and their sources. Background values are also presented on data summary tables for comparative purposes. These values need to be taken into account when making risk management decisions, since concentrations of inorganic contaminants can be naturally elevated and exceed screening values. Qualitative discussion is provided when inorganic contaminants that were retained as COCs were present in concentrations comparable to background. Some contaminants were present in some media for which no suitable benchmark values were available. In these instances, these contaminants were conservatively retained as COCs and qualitatively assessed.

Data used to obtain representative exposure point contaminant concentrations were those generated from RI sampling activities. Sampling locations are shown in Figures 2-3 and 2-4. Area A surface water and sediment data are summarized in Tables 4-22 through 4-26. Sample-specific data are presented in Appendix A.

For total metals in Area A surface water, cadmium, copper, and lead exceeded BTVs and were retained as COCs, and the EEI value equaled 21.67 (Table 6-57). The EEI value for organics in surface water was 14.94, although organics bromomethane, carbon disulfide, chloroethane, and chloromethane were conservatively retained as surface water COCs since no BTVs were available (Table 6-58).

Of the sediment inorganics at Area A, several COCs exceeded BTVs and were retained as COCs, and beryllium and vanadium were conservatively retained since no suitable BTVs were available (Table 6-59). The total EEI for sediment inorganics was 144.24. Several sediment organics exceeded BTVs and were retained as COCs and acetone, 1,2-Dichloroethene, 2-Butanone, and carbazole were conservatively retained as COCs since no suitable BTVs were available (Table 6-60). PAHs comprised most of the elevated EEQ values for organics in sediment. In addition, PCBs (Aroclor 1254 and 1260) and 4,4'-DDT had EEQs indicative of high potential risk. The EEI value for organics was 2153.4.

6.8.6 Uncertainty Analysis

Uncertainty is associated with all aspects of the ERA process. This section provides a summary of the uncertainties involved in this ERA, with a discussion of how they may affect the final risk values and conclusions. Once an ERA is complete, the results must be reviewed and evaluated to identify the types and magnitudes of uncertainties involved. Relying on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the process can be misleading. If numerous conservative assumptions are combined in the ERA process, the resulting calculations will propagate the

TABLE 6-57

SELECTION OF ECOLOGICAL CONTAMINANTS OF CONCERN FOR SURFACE WATER INORGANICS (TOTAL METALS) - AREA A

NAWC WARMINSTER, PENNSYLVANIA

(µg/l)

CONTAMINANT OF POTENTIAL CONCERN	EXPOSURE CONCENTRATION	BENCHMARK (µg/l)	ECOLOGICAL EFFECTS QUOTIENT (EEQ)	RETAINED AS COC? (1)
BARIUM	172	1000	0.17	NO
CADMIUM	2.5	1.15	2.17	YES
CHROMIUM (TOTAL)	4	199.59	0.02	NO
COPPER	106	12.79	8.29	YES
LEAD	28.5	3.01	9.47	YES
MANGANESE	486	14500	0.03	NO
NICKEL	82.75	176.92	0.47	NO
THALLIUM	2	40	0.05	NO
ZINC	117	117.65	0.99	NO
ECOLOGICAL EFFECTS INDEX (EEI)			21.67	

1: COPC was retained as a COC if the benchmark was exceeded or no benchmark was available

TABLE 6-58

SELECTION OF ECOLOGICAL CONTAMINANTS OF CONCERN FOR SURFACE WATER ORGANICS - AREA A

NAWC WARMINSTER, PENNSYLVANIA

(µg/l)

CONTAMINANT OF POTENTIAL CONCERN	EXPOSURE CONCENTRATION	BENCHMARK (µg/l)	ECOLOGICAL EFFECTS QUOTIENT (EEQ)	RETAINED AS COC?
Volatile Organic Chemicals				
BENZENE	0.2	530	0.00	NO
BROMOMETHANE	0.5	NA		YES
2-BUTANONE	4	322000	0.00	NO
CARBON DISULFIDE	5.5	NA		YES
CHLOROETHANE	3	NA		YES
CHLOROMETHANE	4	NA		YES
1,1-DICHLOROETHANE	0.95	20000	0.00	NO
TETRACHLOROETHENE	1	840	0.00	NO
TRICHLOROETHENE	2	21900	0.00	NO
Semivolatile Organic Chemicals				
BENZ(A)ANTHRACENE	0.1	6.3	0.02	NO
BENZO(B)FLUORANTHENE	0.2	30	0.01	NO
CHRYSENE	0.2	30	0.01	NO
DI-N-OCTYLPHTHALATE	0.2	0.3	0.67	NO
DIETHYLPHTHALATE	0.2	3	0.07	NO
FLUORANTHENE	0.3	398	0.00	NO
PYRENE	0.3	30	0.01	NO
Semivolatile Organic Chemicals				
4,4'-DDD	0.0092	0.06	0.15	NO
4,4'-DDT	0.014	0.001	14.00	YES
ECOLOGICAL EFFECTS INDEX (EEI)			14.94	

1: COPC was retained as a COC if the benchmark was exceeded or if no benchmark was available

NA = No benchmark available.

TABLE 6-59

SELECTION OF ECOLOGICAL CONTAMINANTS OF CONCERN IN SEDIMENT: INORGANICS - AREA A

NAWC WARMINSTER, PENNSYLVANIA

(mg/kg)

CONTAMINANT OF POTENTIAL CONCERN	EXPOSURE CONCENTRATION	BENCHMARK (mg/kg)	ECOLOGICAL EFFECTS QUOTIENT (EEQ)	RETAINED AS COC? (1)
ARSENIC	14.1	8.2	1.72	YES
BARIUM	1060	500	2.12	YES
BERYLLIUM	2.1	NA		YES
CADMIUM	8.4	1.2	7.00	YES
CHROMIUM	224	26	8.62	YES
COBALT	75.2	50	1.50	YES
COPPER	136	34	4.00	YES
LEAD	404	46.7	8.65	YES
MANGANESE	11400	460	24.78	YES
MERCURY	2.25	0.15	15.00	YES
NICKEL	224	20.9	10.72	YES
SELENIUM	1.9	1	1.90	YES
SILVER	2	1	2.00	YES
VANADIUM	157	NA		YES
ZINC	8435	150	56.23	YES
ECOLOGICAL EFFECTS INDEX (EEI)			144.24	

1: COPC was retained as a COC if the benchmark was exceeded or if no benchmark was available

NA = No benchmark available.

TABLE 6-60 (PAGE 1 OF 2)

SELECTION OF ECOLOGICAL CONTAMINANTS OF CONCERN IN SEDIMENT: ORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(µg/kg)

CONTAMINANT OF POTENTIAL CONCERN	EXPOSURE CONCENTRATION	BENCHMARK (µg/kg)	ECOLOGICAL EFFECTS QUOTIENT (EEQ)	RETAINED AS COC? (1)
Volatile Organic Chemicals				
ACETONE	108	NA		YES
CARBON TETRACHLORIDE	28	NAP		NO
CHLOROFORM	14.75	6300	0.00	NO
CHLOROMETHANE	21	NAP		NO
1,1-DICHLOROETHENE	3	NAP		NO
1, 2-DICHLOROETHENE (TOTAL	18.33	NA		YES
ETHYLBENZENE	4	NAP		NO
TETRACHLOROETHENE	130	57	2.28	YES
2-BUTANONE	45	NA		YES
TOLUENE	82	NAP		NO
1,1,1-TRICHLOROETHANE	2	NAP		NO
TRICHLOROETHENE	1300	1600	0.81	NO
XYLENE (TOTAL)	19	NAP		NO
Semivolatile Organic Chemicals				
ACENAPHTHENE	3500	16	218.75	YES
ACENAPHTHYLENE	270	44	6.14	YES
ANTHRACENE	8300	85.3	97.30	YES
BENZ(A)ANTHRACENE	20000	261	76.63	YES
BENZO(A)PYRENE	17000	430	39.53	YES
BENZO(B)FLUORANTHENE	25000	3200	7.81	YES
BENZO(G,H,I)PERYLENE	13000	670	19.40	YES
BENZO(K)FLUORANTHENE	20000	3200	6.25	YES
BIS(2-ETHYLHEXYL)PHTHALATE	7900	1300	6.08	YES
BUTYLBENZYLPHTHALATE	380	63	6.03	YES
CARBAZOLE	5700	NA		YES
CHRYSENE	24000	384	62.50	YES
DI-N-BUTYLPHTHALATE	310	6200	0.05	NO
DI-N-OCTYLPHTHALATE	860	6200	0.14	NO
DIBENZ(A,H)ANTHRACENE	5300	63.4	83.60	YES
DIBENZOFURAN	2400	540	4.44	YES
FLUORANTHENE	43000	600	71.67	YES
FLUORENE	5900	19	310.53	YES
INDENO(1,2,3-CD)PYRENE	14000	600	23.33	YES
2-METHYLNAPTHALENE	320	70	4.57	YES
4-METHYLPHENOL	1400	670	2.09	YES
NAPHTHALENE	530	160	3.31	YES
PYRENE	40000	665	60.15	YES

TABLE 6-60 (PAGE 2 OF 2)

SELECTION OF ECOLOGICAL CONTAMINANTS OF CONCERN IN SEDIMENT: ORGANICS - AREA A
NAWC WARMINSTER, PENNSYLVANIA
(µg/kg)

CONTAMINANT OF POTENTIAL CONCERN	EXPOSURE CONCENTRATION	BENCHMARK (µg/kg)	ECOLOGICAL EFFECTS QUOTIENT (EEQ)	RETAINED AS COC? (1)
Pesticides and PCBs				
4,4'-DDD	130	16	8.13	YES
4,4'-DDE	12.6	2.2	5.73	YES
4,4'-DDT	600	1	600.00	YES
ALDRIN	78.5	100	0.79	NO
ALPHA-CHLORDANE	2.7	100	0.03	NO
AROCLOR-1016	110	NAP		NO
AROCLOR-1248	1500	NAP		NO
AROCLOR-1254	615	5	123.00	YES
AROCLOR-1260	1500	5	300.00	YES
DELTA-BHC	3.2	100	0.03	NO
DIELDRIN	4.8	NAP		NO
ENDOSULFAN II	11	5.4	2.04	YES
ENDOSULFAN SULFATE	8.8	NAP		NO
ENDRIN	48	100	0.48	NO
ENDRIN ALDEHYDE	44	100	0.44	NO
ENDRIN KETONE	10	100	0.10	NO
GAMMA-CHLORDANE	7.1	100	0.07	NO
ECOLOGICAL EFFECTS INDEX (EEI)			2153.4	

1: COPC was retained as a COC if it exceeded the benchamark value or no benchmark was available
NA = No benchmark available.
NAP = Not applicable since frequency of detection is <5%.

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uncertainties associated with each of those assumptions. The resulting bias is toward overpredicting risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

Generally, risk assessments carry two types of uncertainty: measurement and informational. Measurement uncertainty refers to the variability inherent in measured data. The risk assessment reflects the accumulated variances of the individual values used for several different parameters. Informational uncertainty stems from the limited availability of necessary information. Often the gap between what is needed and what is available is significant; information regarding the effects of some contaminants on wildlife receptors, the biological mechanism of a contaminant, the impact of physiological differences on exposure pathways, or the behavior of a contaminant in various environmental media is often absent.

- Uncertainty is associated with each of the steps of the risk assessment process:

- Uncertainty in preliminary problem formulation can result from limited information regarding contaminant sources, release mechanisms, and exposure routes.

- Uncertainty in the ecological effects characterization arises from the quality of the existing benchmark values and toxicity data to support a determination of potential adverse impacts to ecological receptors.

- Uncertainty associated with the exposure assessment includes the methods used and the assumptions made to determine exposure point concentrations.

- Uncertainty in risk characterization includes that associated with the potential effects of exposure to multiple contaminants and the cumulative uncertainty from combining conservative assumptions made in earlier activities.

6.8.6.1 Uncertainty in the Preliminary Problem Formulation

The site investigated in this ERA received contaminant inputs from more than one source, although initially contaminants are conservatively assumed to stem directly from area-related activities. Each of the areas had multiple contaminant sources of concern specific to the area, but the waterways also receive contaminant inputs from roadway and parking lot runoff (e.g., roads, parking lots, and other developed areas near Area B) as well as from off-site sources, including residential developments and commercial businesses. Since contaminant concentrations may reflect inputs from many sources, uncertainties exist regarding whether risk characterized at a discrete area stems from area-related contaminants. Also, different sites and their contaminants may possess different contaminant exposure routes for ecological receptors. Difficulties and limitations exist in trying to obtain exposure routes for individual sites for

individual receptors. Since exposure routes may be quite different for different species, risk may be over- or underestimated if this information is not known.

6.8.6.2 Uncertainty in the Ecological Effects Characterization

A great deal of uncertainty in this risk assessment arises from the nature and quality of the available toxicity data used to derive BTVs. This uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose related; and when postulated mechanisms of toxicity are similar for laboratory and wildlife species. Most benchmark values are based on the most conservative assumptions possible. As such, though an inherent level of conservatism is needed in a screening-level ecological risk assessment to ensure that the most sensitive receptors are protected, conservative BTVs may heavily overestimate potential risks and the resulting EEQ values may be misleading. Both AWQCs and most sediment screening values used in this assessment are based on laboratory studies that do not take into account mitigating or ameliorating physical and chemical conditions in the environment. Therefore, uncertainty is introduced into the assessment, and the results tend to overestimate potential risks.

In addition, ERAs, unlike human health risk assessments, must consider risks to many different species. However, calculation of risk values for each potential receptor species is not possible. For this ERA, conservative BTVs protective of a wide range of ecological receptors were sought. The underlying assumption associated with the use of these benchmarks is that contaminant concentrations in excess of these BTVs are indicative of potential impacts to actual receptors inhabiting the area. However, species-specific physiological differences that may influence an organism's response to a contaminant or subtle behavioral differences that may increase/decrease a receptor's contact with a contaminant are seldom known. Also, some contaminants were present in some media for which no suitable BTVs were available, and as a result, they could not be quantitatively assessed. For these reasons, the use of benchmark values, while necessary, will introduce error into the results of an assessment.

6.8.6.3 Uncertainty in the Exposure Assessment

Uncertainty in the exposure assessment arises mainly in the methods used to obtain exposure point concentrations. The maximum detected contaminant concentrations were generally used to represent the highest contaminant concentrations to which ecological receptors might be exposed. If the samples evaluated in this ERA are representative of contaminant concentrations associated with the station, then this approach is conservative and should overestimate potential risks to ecological receptors. The maximum concentration of a contaminant in a given medium may have been collected in a "hot spot" of contamination and may be much higher than the remaining values in the data set. Again, although use of maximum values is appropriate for screening in an ERA, they may grossly overpredict potential risks.

6.8.6.4 Uncertainty in the Risk Characterization

All aspects of the ERA process described in the above sections affect uncertainty in the risk characterization. Uncertainty in risk characterization also stems, in part, from the fact that this process does not fully or toxicologically consider antagonistic or synergistic effects. Little or no information is available to determine the potential for antagonism or synergism for the contaminants evaluated. As mentioned above, the EEI is only an additive measure of total potential risk. Toxicity may actually increase, or even decrease, geometrically based on synergistic or antagonistic effects. Additionally, contaminants that account for a large percentage of potential risk may be mitigated by several factors, including a low frequency of detection or elevated concentrations in areas with no significant habitat. For these reasons, the EEI can be used as a rough estimate of total risk, but it contains uncertainty and must be interpreted with caution.

6.8.7 ERA CONCLUSIONS FOR AREA A

Area A is located in the northwestern section of NAWC Warminster. The area is situated along a tributary of Little Neshaminy Creek. Contaminant inputs from suspected Area A sources were the focus of this assessment. Surface water runoff from these sites enters the tributary, as does a minor amount of localized perched water within the unsaturated zone. Aquatic habitat is limited in the tributary near Area A, but increases in quantity and quality as the tributary exits the installation boundaries. Wetland areas are located downstream of the stretch of the tributary near NAWC Warminster.

EEQ values for dissolved and total metals in surface water were indicative of relatively low potential risk, although the EEQs for both forms of lead were indicative of low to moderate risk. Yet, total lead was only detected in one-third of the surface water samples collected and dissolved lead was only detected in two of fifteen samples. Antimony was conservatively retained as a dissolved COC in surface water since no suitable BTV was available, but was only detected in one of fifteen samples. Potential risk from organics in surface water were negligible. Four organics were conservatively retained as COCs since no surface water BTVs were available, but were all detected in only one sample and in relatively low maximum concentrations (near detection limits).

In sediments, several inorganics had EEQs indicative of low to moderate potential risk. In particular, lead, manganese, mercury, and zinc accounted for the majority of the elevated EEI value for sediment inorganics. The maximum concentration of zinc was comparable to the maximum concentration of zinc detected in background samples. Beryllium and vanadium were conservatively retained as sediment COCs since no suitable BTVs were available, but beryllium was only detected in a maximum concentration slightly above background. The maximum concentration of vanadium was elevated, but most of the other positive detections were an order of magnitude lower than the maximum. Most of the maximum concentrations of

inorganic COCs in Area A sediments were detected in samples A5 through A8, and samples A23, A25, and A26. These sampling locations are located adjacent to or near Site 2. The concentrations of most metals in samples taken further downstream (samples A14 through A16) were much lower and near or below BTVs, with the exception of lead, manganese, and zinc. In general, these three metals were elevated in samples taken slightly downstream (samples A14, A15, A16). However, concentrations of these three metals, and all others, were relatively low in samples A11 through A13, which were collected far downstream near Bristol Road.

For sediment organics, a multitude of PAHs had EEQs indicative of moderate to high potential risk. Frequencies of detection were high for most of these compounds and elevated concentrations were detected in samples taken several hundred feet from the base property boundary. Concentrations of some PAHs, including chrysene, fluoranthene, phenanthrene, and pyrene were also elevated in samples A11 through A13, which were collected far downstream of Area A, but were not as high as those detected on the installation. The developed areas and roadways located along the tributary near samples A-11 through A-13 could contribute, at least in part, to the elevated PAH concentrations at these locations.

In addition, the organochlorine pesticide 4,4'-DDT and the PCB mixtures Aroclor-1254 and -1260 had relatively high EEQs, but the maximum detected concentration of 4,4'-DDT was one or two orders of magnitude higher than all of the other detections, suggesting a "hot spot" of contamination. Also, Aroclor 1260 was only detected in 3 of 21 samples; Aroclor-1254 was detected in roughly half of all samples and the maximum detected concentration was an order of magnitude higher than most of the other positive detections. Four organics were detected in sediments for which no suitable benchmarks were available. These compounds had low frequencies of detection, with the exception of carbazole. Several elevated concentrations of carbazole were detected.

In summary, potential risks from metals in surface water in the tributary of Little Neshaminy Creek are generally indicative of low potential risk, as are potential risks from surface water organics. In sediments, inorganic EEQs were also mostly indicative of low potential risk, although some elevated EEQs were calculated for lead, manganese, and zinc and concentrations of these metals were elevated downstream from Area A. EEQs for PCBs and some pesticides were indicative of moderate to high potential risk, but potential risks were heavily mitigated by several factors. Potential ecological risks for several PAHs in sediment were moderate to high, and frequencies of detection were generally high. Also, elevated concentrations of some PAHs were detected in samples taken several hundred feet from Area A and far downstream of Area A near Bristol Road. Heavily developed areas exist off-base near the tributary that could contribute PAHs to the waterway.

The presence of elevated PAH concentrations in sediment samples adjacent to Area A suggests significant contaminant inputs in the stretch of the stream just north of Sites 2 and 3. However, this stretch receives stormwater discharges and overland runoff from large paved parking areas at the base and Jacksonville

Road. Additional sampling and analysis would be necessary to differentiate between potential sources and characterize any related Area A impacts.

Total organic carbon (TOC) data were also collected for sediment samples at Area A. TOC concentrations for samples A14, A15, and A16, which were taken several hundred feet from the base boundary, were slightly higher than EPA's (1996) suggested average value of 1 percent (1.4 to 2.7 percent). Since TOC is known to bind organics and decrease their bioavailability, the site-specific toxicity of PAHs may be ameliorated. Conversely, sediment grain size analysis for samples A15 through A18 indicated that sediments slightly downstream of Area A were sandy to silty (approximately 35 percent of particles passing through a 60 um sieve). These types of substrates tend to have fewer binding sites for organic contaminants than finer silty to clayey sediments, increasing bioavailability. Therefore the bioavailability of sediment contaminants at Area A is unknown.

The combination of several PAHs and metals in sediments indicates the potential for toxic effects to aquatic organisms and semi-aquatic receptors that feed on them. Potential ecological risks were estimated by comparing stream sediment sample analytical results to published conservative benchmarks established for sensitive receptors. The greatest estimated and potential risk identified was associated with sediment contamination in the stretch of the stream north of Sites 2 and 3. However, this stretch also receives stormwater discharges and overland runoff from large paved parking areas at the base and Jacksonville Road. Additional sampling and analysis might be needed to differentiate between potential sources of contamination other than the Area A sites themselves and to better characterize any related acute or chronic impacts or risks to ecological receptors.

7.0 FEASIBILITY STUDY

7.1 INTRODUCTION

Based on the RI results, this feasibility study (FS) was prepared for contaminated sediment associated with the stream adjacent to Area A stream as well as contaminated soils associated with Area A. This FS develops and evaluates potential remedial alternatives for addressing unacceptable risks to human health at Area A and ecological receptors associated with the stream. The estimated human health risks were summarized in Section 6.6. The potential ecological risks were evaluated in Section 6.8. The results of the ecological risk assessment indicated that Area A sediment poses a potential for toxic effects to aquatic organisms.

7.1.1 Area A Soils

For Area A surface and subsurface soils, no unacceptable carcinogenic or noncarcinogenic risks were present above EPA's target risk levels of 1×10^{-4} and 1.0, respectively, for the industrial land use. Industrial use is the reasonably anticipated land use for Area A. While not reasonably anticipated, soils at Site 1, Site 2, Site 3 and the Impoundment Area were determined to present unacceptable non-carcinogenic risks under potential residential use. In this case, institutional controls should be implemented to limit reuse of Area A to industrial/commercial purposes. In addition, the RI indicated that Area A soils present a potential threat to stream sediment and associated ecological receptors. As such, this FS evaluates alternatives for preventing the potential migration of soil contaminants to the nearby Area A stream.

7.1.2 Area A Sediment

The RI indicated that Area A sediment presents a potential threat to ecological receptors. As a result, remedial technologies and process options for Area A sediment were evaluated and screened to select those that are most viable for the site conditions and contaminants. The technologies and process options that passed the screening process were combined to form remedial alternatives that will address site contamination. The remedial alternatives were then evaluated to distinguish positive and negative aspects of each alternative and then compared to one another.

Potential risks from metals in surface water in the tributary of Little Neshaminy Creek were generally indicative of low potential risk, as were potential risks from surface water organics. In sediment, inorganic Environmental Effects Quotients (EEQs) were also mostly indicative of low potential risk, although some elevated EEQs were calculated for lead, manganese, and zinc and concentrations of these metals were elevated downstream from

Area A. EEQs for PCBs and some pesticides were indicative of moderate to high potential risk, but potential risks were heavily mitigated by several factors. Potential ecological risks for several PAHs in sediment were moderate to high, and frequencies of detection were generally high. Also, elevated concentrations of some PAHs were detected in samples taken several hundred feet from Area A and far downstream of Area A near Bristol Road. Heavily developed areas exist off-base near the tributary that could contribute PAHs to the waterway, but the presence of elevated concentrations of PAHs and metals in sediment samples adjacent to Area A suggested significant contaminant inputs from base-related activities.

7.2 REMEDIAL ACTION OBJECTIVES

Stream sediment adjacent to Area A was determined to present estimated potential risks to ecological receptors. In response, one objective of remedial action is to mitigate these potential risks. In addition, Area A soil contaminants were determined to present a potential threat to ecological receptors if allowed to migrate to surface water and sediment. In this case, a second remedial action objective is to prevent such migration. Finally, while not reasonably anticipated, Area A soils present a potential unacceptable risk to human health under residential use. In this case, institutional controls should be implemented to preclude residential use.

7.2.1 Chemicals and Media of Concern

Stream sediments exceeding ecological benchmark values in Section 6.8 were determined to present potential ecological effects. The specific contaminants of concern (COCs) in this case are identified below. Sediment COC concentrations that are protective of ecological receptors are considered to the preliminary remediation goals for these COCs and appear in Section 7.3.1.

The ecological COCs addressed in this FS are as follows:

Inorganics		
Arsenic	Cobalt	Nickel
Barium	Copper	Selenium
Beryllium	Lead	Silver
Cadmium	Manganese	Vanadium
Chromium	Mercury	Zinc

Organics

1,2-Dichloroethene (total)	Aroclor-1254	Chrysene
2-Butanone	Aroclor-1260	Dibenzo(a,h)anthracene
2-Methylnapthalene	Benzo(a)anthracene	Dibenzofuran
4,4'-DDD	Benzo(a)pyrene	Endosulfan II
4,4'-DDE	Benzo(b)fluoranthene	Fluoranthene
4,4'-DDT	Benzo(g,h,i)perylene	Fluorene
4-Methylphenol	Benzo(k)fluoranthene	Indeno(1,2,3-cd)pyrene
Acenaphthene	Bis(2-ethylhexyl)phthalate	Naphthalene
Acenaphthylene	Butylbenzylphthalate	Pyrene
Acetone	Carbazole	Tetrachloroethene
Anthracene		

Soils that present a potential threat to ecological receptors, if allowed to migrate to stream sediment via surface runoff, are those soils that contain contaminant concentrations exceeding surface soil PRGs protective of sediment as identified in Section 7.3.2. The COCs in surface soils include the following:

Inorganics

Cadmium

Copper

Lead

Silver

zinc

Organics

Anthracene

Benzo(a)anthracene

Benzo(a)pyrene

Benzo(g,h,i)perylene

Dibenzo(a,h)anthracene

Fluoranthene

Indeno(1,2,3-cd)pyrene

In addition, any subsurface soil concentrations in Area A that exceed the surface soil PRGs identified in Section 7.3.1 would present a potential threat to ecological receptors if they were excavated, placed on the ground surface, and allowed to migrate to the stream via surface runoff.

While the RI determined that Area A soil contaminants may potentially migrate to the nearby stream via subsurface flow, the extent of such potential migration cannot be reasonably quantified. It has been assumed that the surface soil PRGs referenced above would be protective of this pathway.

7.2.2 Compliance with ARARs and TBC Criteria

ARARs consist of any standard, requirement, criterion, or limitation under federal environmental law and any promulgated standard, requirement, criteria, or limitation under a state environmental or facility-siting law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

To be considered (TBC) criteria are nonpromulgated, nonenforceable guidelines or criteria that may be useful for developing a remedial action or are necessary for determining what is protective to human health and/or the environment. Examples of TBC criteria include EPA Drinking Water Health Advisories, Reference Doses, and Cancer Slope Factors.

ARARs fall into three categories, based on the manner in which they are applied. The characterization of these categories is not perfect, because many requirements are combinations of the three types of ARARs. These ARAR categories can be described as contaminant-specific [e.g., Clean Water Act (CWA) Ambient Water Quality Criteria), location-specific (e.g., wetland regulations), and action-specific (e.g., off-base disposal of wastes). Table 7-1 presents a summary of the more relevant ARARs and TBCs addressed in this FS.

7.2.2.1 Contaminant-Specific ARARs

The Clean Water Act (CWA) sets EPA Ambient Water Quality Criteria (AWQCs) that are non-enforceable guidelines developed for pollutants in surface waters pursuant to Section 304(a)(1) of the CWA. Although AWQCs are not legally enforceable, they have been used by many states to develop enforceable water quality standards; they should be considered as potential ARARs, as specified by CERCLA. AWQCs are available for the protection of human health from exposure to contaminants in surface water as well as from ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. Table 7-2 presents AWQCs for COCs addressed in this FS.

TABL -1
SUMMARY OF ARARs AND TBC CRITERIA FOR AREA A SEDIMENT
NAWC WARMINISTER, PENNSYLVANIA

Requirement	Citation	Status	Synopsis	Comment
Contaminant-Specific ARARs and TBC				
Clean Water Act (CWA) Ambient Water Quality Standards	33 USC 1251 et seq. Section 304(a)(1)	TBC	Water quality criteria are non-enforceable guidance and are used by the state in conjunction with the designed use for a stream segment to establish water quality standards under CWA 303.	During remedial activities, treatment by-products may be collected. AWQCs are TBC if this water is discharged to surface waters.
Pennsylvania Water Quality Standards	PA Code, Title 25, Chapter 16 and 93	Potentially Applicable	Standards applicable for actions involving the discharge of pollutants to surface water. Based upon water uses that are protected and will be considered by PADEP.	During remedial activities, groundwater or treatment by-products may be collected. AWQCs are applicable if this water is discharged to surface waters.
Location Specific ARARs and TBC				
Federal Protection of Wetlands Executive Order	E.O. 11990	Potentially Applicable	Requires the action of federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance the natural and beneficial values of wetlands.	Wetlands were assessed along the unnamed tributary of Little Neshaminy Creek. Retained in the event that wetland areas are affected.
The Fish and Wildlife Coordination Act	16 USC 661	Potentially Applicable	Protects fish and wildlife when federal actions result in the control or modification of a natural stream or body of water.	Applicable if surface water is diverted or disturbed during remedial actions.
The Fish and Wildlife Improvement Act of 1978	16 USC 742a	Applicable	This Act protects fish and wildlife against impacts that may affect their protected habitats.	Applicable because fish are present in Area A surface water, and wildlife is present in Area A.
The Fish and Wildlife Conservation Act of 1980	16 USC 2901	Applicable	This Act protects fish and wildlife against impacts that may affect their protected habitats.	Applicable because fish are present in Area A surface water, and wildlife is present in Areas A.
Federal Floodplain Management	E.O. 11988	Potentially Applicable	Requires federal agencies to evaluate the potential effects of impacts associated with occupancy and modification of a floodplain.	Applicable if surface water is diverted or disturbed during remedial actions.
Action Specific ARARs and TBC				
RCRA Subtitle D	40 USC 6901	Potentially Applicable	Establishes design and operating criteria for solid waste (nonhazardous) landfills.	Potentially applicable if sediment is determined to be nonhazardous.
RCRA Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Potentially Applicable	Criteria to determine which solid waste disposal facilities pose a probability of adverse health effects and therefore prohibit open dumps.	Applicable if sediment is stockpiled at various locations on site.
Department of Transportation (DOT) Rules for Hazardous Materials Transport	49 CFR Parts 107 and 171 - 179	Potentially Applicable	Regulations for the transportation of hazardous materials. Requirements cover packaging, marking, labeling, and transportation methods.	Off site shipments of any contaminated sediment that is classified as a hazardous material from this site would have to comply with these regulations.

TABLE 7-1
SUMMARY OF ARARs AND TBC CRITERIA FOR AREA A SEDIMENT
NAWC WARMINISTER, PENNSYLVANIA

Requirement	Citation	Status	Synopsis	Comment
The Clean Water Act (CWA) - National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122	Potentially Applicable	Regulations for discharge, dredge, or fill materials and oil or hazardous waste spills into the United States waters.	These requirements are applicable for all alternatives that include a water discharge.
National Environmental Policy Act (NEPA)	42 USC 4321 40 CFR Part 6	Potentially Applicable	Act, that requires federal agencies to evaluate the environmental impacts associated with major actions that they fund, support, permit, or implement.	Alternatives could constitute significant activities, thereby making NEPA requirements ARARs. Activities conducted in accordance with the NCP are considered to meet the substantive NEPA requirements.
The Occupational Health and Safety Act	29 USC Sections 651 through 678	Potentially Applicable	Act that regulates worker health and safety during implementation of remedial actions.	As this is a federal Superfund site, these regulations are applicable to all investigations and remedial activities at NAWC Warminster.
Pennsylvania Solid Waste Disposal Regulations	PA Code 25, Chapter 75	Potentially Applicable	Regulations that establish the disposal of solid wastes including municipal and industrial materials.	Applicable for removal of site solid wastes including municipal and industrial materials.
Pennsylvania Industrial Waste Management Regulations	PA Code 25, Chapter 97	Potentially Applicable	Rules that regulate the disposal of industrial waste materials.	Applicable for removed site wastes that are classified as industrial.
Pennsylvania Stormwater Management Act	Act No. 167	Potentially Applicable	Act that requires measures to control stormwater runoff during remedial alternatives or development of land.	Required if remedial actions take place.
Pennsylvania Special Water Pollution Regulations	PA Code, Title 25, Chapter 101	Potentially Applicable	Regulations, that establish a procedure for mandatory notification of downstream users in the case of an accident in which a toxic substance enters, surface waters.	These regulations may be applicable for remedial actions that include on-base treatment of sediment.
Pennsylvania Erosion Control Regulations	PA Code, Title 25, Chapter 102	Potentially Applicable	Regulations which requires measures to control stormwater runoff during remedial alternatives or development of land.	These regulations may be potentially applicable if remedial actions disturb sediments at the site.
Pennsylvania Hazardous Substances Transportation Regulations	PA Code, Title 13 and Title 15	Potentially Applicable	Regulations that govern the transport of flammable liquids and solids, oxidizing materials, poisons, and corrosive liquids.	Off-site shipments of any contaminated sediment that is classified as a hazardous material would have to comply with these regulations.

Pennsylvania Water Quality Standards (PA Code, Title 25, Chapter 16 and 93) are based upon water uses that are to be protected and will be considered by PADEP in its regulation of discharges to surface water. The standards may be applicable for actions involving the discharge of pollutants to surface water. Chapter 93.5 specifies the procedures for applying water quality criteria for discharge of pollutants including design conditions (i.e., the use of stream flow rates) that are potentially applicable to discharge of treated groundwater from the sites. Chapter 93.9 provides designations to site-specific surface waters based on drainage areas of river basins in question. Little Neshaminy Creek is designated as a second generation tributary of the Delaware River. This designation may be potentially useful for applying the designated water use and specific water quality criteria (if any) for potential on-base treatment requirements of contaminated sediment (i.e., process water from sediment treatment). Also, Chapter 16 contains ambient water quality criteria for toxics for the protection of human health and aquatic life. Table 7-2 provides state water quality standards applicable to surface waters in Pennsylvania.

7.2.2.2 Location-Specific ARARs and TBC Criteria

Federal Protection of Wetlands Executive Order (E.O. 11990) requires federal agencies, in carrying out their responsibilities, to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. According to the published definition of national wetlands, Federal Register 40 CFR Appendix C, several small areas of palustrine forested wetlands are present along intermittent tributaries to Little Neshaminy Creek or Southampton Creek. This ARAR has been retained in the event that wetland areas may be affected.

The Fish and Wildlife Coordination Act (16 USC 661) provides for consideration of the impacts on wetlands and protected habitats. The act requires that federal agencies, before issuing a permit or undertaking federal action for the modification of any body of water, consult with the appropriate state agency exercising jurisdiction over wildlife resources to conserve those resources. Consultation with the United States Fish and Wildlife Service is also required.

The Fish and Wildlife Improvement Act of 1978 (16 USC 742a) and The Fish and Wildlife Conservation Act of 1980 (16 USC 2901) provide for consideration of the impacts on wetlands and protected habitats. Federal Floodplain Management Executive Order (E.O. 11988) requires federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with occupancy and modification of flood plains.

TABLE 7-2
FEDERAL AND STATE WATER QUALITY STANDARDS AND AWQCs FOR AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs[4]	Federal AWQC for Ingestion[1] (Mg/L)		State AWQC for Protection of Aquatic Life[2] (µg/L)		State AWQC for Protection of Human Health[2] (µg/L)	State Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
	Water and Organisms	Organisms	Continuous Concentration	Maximum Concentration		
INORGANICS						
Antimony	14	4,300	219	1095	10	6/600
Arsenic	.0018	0.14	190[8]	360[8]	50	50 / 5,000
Barium	NA	NA	4,100	20,500	1,000	2000 / 200,000
Cadmium	NA	NA	1.0[3][8]	3.7[3][8]	10	5 / 500
Chromium	NA	670,000	10[7][8]	15[3][7][8]	NP	100 / 10,000[6]
Cobalt	NA	NA	19	95	NP	None
Copper	1300	NA	11[3][8]	17[3][8]	1,000	1,000 / 100,000
Lead	50	NA	2.5[3][8]	65[3][8]	50	5 / 500
Manganese	50	100	NP	NP	NP	1, 000[9]
Mercury	0.14	0.15	0.012	2.1[8]	0.144	2 / 200
Nickel	610	4,600	160[3][8]	1,400[3][8]	600	100 / 10,000
Silver	NA	50	NP	3.5[3][8]	200	100 / 10,000
Vanadium	NA	NA	103	515	NP	None
Zinc	NA	NA	100[3][8]	110[3][8]	5,000	None
ORGANICS						
Acenaphthene	1,200	2,700	17	85	20	None
Acenaphthylene	NA	NA	NP	NP	NP	None
Acetone	NA	NA	86,000	446,000	4,000	None
Anthracene	9,600	110,000	NP	NP	10,000	None

TABL)-2
FEDERAL AND STATE WATER QUALITY STANDARDS AND AWQCs FOR AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs[4]	Federal AWQC for Ingestion[1] (Mg/L)		State AWQC for Protection of Aquatic Life[2] (µg/L)		State AWQC for Protection of Human Health[2] (µg/L)	State Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
	Water and Organisms	Organisms	Continuous Concentration	Maximum Concentration		
Aroclor-1254	4.4E-05	4.5E-05	0.014	1.0	0.00004	0.5150
Aroclor-1260	4.4E-05	4.5E-05	0.014	1.0	0.00004	0.5150
Benzo(a)anthracene	0.0028	0.031	0.1	0.5	0.003	None
Benzo(a)pyrene	0.0028	0.031	NP	NP	0.003	0.2 / 20
Benzo(b)fluoranthene	NA	NA	NP	NP	0.003	None
Benzo(g,h,i)perylene	NA	NA	NP	NP	NP	None
Benzo(k)fluoranthene	0.0028	0.031	NP	NP	0.003	None
Bis(2-ethylhexyl)phthalate	1.8E-03	5.9E-3	909	4,545	2	6 / 600
2-Butanone	NA	NA	32,200	161,000	2,000	None
Butylbenzylphthalate	3	5.2	35	140	300	None
Carbazole	NA	NA	NP	NP	NP	None
Chrysene	0.0028	0.031	NP	NP	0.003	None
4,4'-DDD	5.9E-04	5.9E-04	0.001	0.55	NP	None
4,4'-DDE	5.9E-04	5.9E-04	0.001	0.55	NP	None
4,4'-DDT	5.9E-04	5.9E-04	0.001	0.55	0.0005	None
Dibenz(a,h)anthracene	0.0028	0.031	NP	NP	0.003	None
Dibenzofuran	NA	NA	NP	NP	NP	None
Cis-1,2-Dichloroethene	NA	NA	NP	NP	NP	70 / 7,000
Trans-1,2-Dichloroethene	700	NA	1,350	6,750	700	100 / 10,000
Endosulfan II	NA	NA	NP	NP	NP	None

TABLE 7-2
FEDERAL AND STATE WATER QUALITY STANDARDS AND AWQCs FOR AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs[4]	Federal AWQC for Ingestion[1] (Mg/L)		State AWQC for Protection of Aquatic Life[2] (µg/L)		State AWQC for Protection of Human Health[2] (µg/L)	State Health Standard for Groundwater[5] (µg/L) ≤ 2500 TDS / > 2500 TDS
	Water and Organisms	Organisms	Continuous Concentration	Maximum Concentration		
Fluoranthene	300	300	40	200	300	None
Fluorene	1,300	14,000	NP	NP	1,000	None
Indeno(1,2,3-cd)pyrene	.00028	.0031	NP	NP	0.003	None
2-Methylnaphthalene	NA	NA	NP	NP	NP	None
4-Methylphenol	NA	NA	NP	NP	NP	None
Naphthalene	NA	NA	43	135	10	20 / 2,000
Pyrene	960	11,000	NP	NP	1,000	None
Tetrachloroethene	0.8	8.85	139	695	0.7	5 / 500

(1) EPA, 1993. Water Quality Criteria Summary-Draft. Office of Science and Technology, Health and Criteria Division (4304), Washington, DC.
(2) 25 PA Code Chapter 16
(3) Based on assumed hardness of 100 µg/L, must be evaluated on a site-specific basis for receiving stream(s) of concern.
(4) COCs include risk-based COCs for soil and ecological COCs for Area A sediment.
(5) PADEP Land Recycling Program Technical Guidance Manual Supplement, November 1996.
(6) Value for total chromium.
(7) Value for Chromium VI.
(8) Dissolved criteria.
(9) 25 PA Code, Chapter 93.
TDS Total Dissolved Solids.
NA Not Available/Not Promulgated

7.2.2.3 Action-Specific ARARs

Action-specific ARARs and TBCs are technology- or activity-based regulatory requirements or guidances that would control or restrict remedial action. The following ARARs and TBCs might relate to remedial action at NAWC Warminster.

RCRA Subtitle D establishes design and operating criteria for solid waste (nonhazardous) landfills. In general, RCRA Subtitle D establishes minimum design and operating criteria for all solid waste landfills that

- Receive municipal solid waste as defined in 40 CFR Part 258
- Codispose sewage sludge with municipal solid waste
- Receive nonhazardous municipal solid waste combustion ash
- Are not regulated under Subtitle C of RCRA

The closure and post-closure care requirements under RCRA Subtitle D may be relevant and appropriate to the contaminated waste fill and soils at the site. These requirements are intended to minimize the infiltration of water into the landfill and maintain the integrity of the cover during the post-closure period by minimizing cover erosion. They include closure and post-closure plans (post-closure plans must include a description of monitoring and maintenance activities as well as a description of any uses of the property during the post-closure period) and minimum requirements for a final landfill cover. In states with EPA-approved programs, the director of the program may approve alternative cover designs. Post-closure care must be conducted for 30 years except in states with EPA-approved programs where the director of the program has the authority to lengthen or shorten the post-closure period.

RCRA Subtitle C regulates the treatment, storage, and disposal of hazardous waste from its generation until its ultimate disposal. In general, RCRA Subtitle C requirements for the treatment, storage, or disposal of hazardous waste will be applicable if the waste is a listed or characteristic waste under RCRA or if the waste was treated, stored, or disposed after the effective date of the RCRA requirements under consideration. The Area A sediments are not considered to be RCRA hazardous waste, based on the available analytical data for sediment samples. Thus, RCRA Subtitle C requirements are not applicable for this FS. Pennsylvania Hazardous Waste Management Regulations (PA Code, Title 25, Article VII) essentially parallel RCRA Subtitle C hazardous waste management regulations and are also not likely to be ARARs.

RCRA Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257) establish criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health and thereby constitute prohibited open dumps.

Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR Parts 107 and 171-179) regulate the transport of hazardous materials, including packaging, shipping equipment, and placarding. These rules are considered applicable to wastes shipped off site for laboratory analysis, treatment, or disposal.

The Clean Water Act (CWA), as amended, governs point-source discharges through the National Pollutant Discharge Elimination System (NPDES), discharge or dredge or fill material, and oil and hazardous waste spills to United States waters. NPDES requirements (40 CFR Part 122) will be applicable if the direct discharge of pollutants into surface waters is part of the remedial action such as dewatering sediments.

National Environmental Policy Act (NEPA) (42 USC 4321 / 40 CFR Part 6) requires federal agencies to evaluate the environmental impacts associated with major actions that they fund, support, permit, or implement. Specifically, NEPA requires federal agencies to consider five issues during the planning of major actions: the environmental impact of the proposed action; any adverse impacts that cannot be avoided with the proposed implementation; alternatives to the proposed action; the relationship between short-term and long-term effects; and any irreversible and irretrievable commitments of resources that would be involved in a proposed action.

The Occupational Health and Safety Act (29 USC, Sections 651 through 678) regulates worker health and safety during implementation of remedial actions.

Pennsylvania Solid Waste Disposal Regulations (PA Code 25, Chapter 75) regulate the disposal of solid wastes including municipal and industrial materials. The regulations set operating and permitting standards for disposal areas and characterize waste materials to achieve proper disposal. Any remedial actions resulting in the generation of waste material for on-base or off-base disposal are governed by these regulations. Pennsylvania Industrial Waste Management Regulations (PA Code 25, Chapter 97) regulate the disposal of industrial waste materials. The regulations characterize wastes and set permitting and disposal standards. Remedial activities resulting in the generation of industrial waste, such as wastewater treatment plant sludges, are regulated under this statute.

Pennsylvania Stormwater Management Act (Act No. 167) requires measures to control stormwater runoff during remedial alternatives or development of land and would be applicable if intrusive activities take place at the site.

Pennsylvania Special Water Pollution Regulations (PA Code, Title 25, Chapter 101) establish a procedure for mandatory notification of downstream users in the case of an accident in which a toxic substance enters surface waters. These regulations also specify bonding requirements for solid waste facilities that would ensure closure of a permitted site in a manner that would abate or prevent water pollution. The regulations may be applicable for remedial actions that include on-site treatment of solid waste.

Pennsylvania Erosion Control Regulations (PA Code, Title 25, Chapter 102) provides requirements for erosion and sedimentation control plans, permits, etc. These regulations may be potentially applicable if remedial actions involve disturbance of Area A sediments.

Pennsylvania Hazardous Substances Transportation Regulations (PA Code, Title 13 and Title 15) govern the transport of flammable liquids and solids, oxidizing materials, poisons, and corrosive liquids. These regulations may be applicable to certain wastes that are shipped off site for laboratory analysis, treatment, or disposal. These regulations are generally equivalent to federal DOT regulations.

7.3 PRELIMINARY REMEDIATION GOALS

7.3.1 Sediment PRGs Protective of Ecological Receptors

Area A sediments were found to pose estimated ecological risk levels. To mitigate these risks to potential ecological receptors, ecological-based PRGs were developed for Area A sediments, as presented in Table 7-3. The chemicals considered for PRG evaluation consist of those chemicals identified as ecological COCs.

Ecological PRGs were primarily gathered from Preliminary Remediation Goals for Ecological Endpoints (Efroymson et al., 1996). Efroymson et al. gathered ecological PRGs from widely accepted sources of ecological benchmarks or derived them with methodologies commonly used to calculate sediment benchmarks. To obtain appropriate PRGs, Efroymson et al. obtained the lowest value for each contaminant from the following sediment toxicity.

- Sediment quality criteria proposed by EPA (EPA, 1996).
- Sediment quality criteria based on chronic AWQC).

- Sediment quality criteria calculated using the lowest chronic value (LCV) for fish, daphnids, or other invertebrates in surface waters.
- NOAA Effects Range-Median (ER-M) values (Long et al., 1995).
- Probable Effects Levels (PELs) from the Florida Department of Environmental Protection (FDEP, 1994).

If values were not available from the sources listed above, Efroymson et al. used either the sediment benchmark calculated using the secondary chronic value for aquatic toxicity or the Ontario Ministry of the Environment Severe Effect Level (SEL) (OME, 1992), whichever was lower. Brief descriptions of these values are provided, as follows.

EPA has published sediment quality criteria for five contaminants (EPA, 1996). Of the five contaminants for which SQC were calculated, two of them, acenaphthene and fluoranthene, were ecological COCs in Area A sediments. However, since lower values were available from the other sources, the SQC for these two organics were not presented as PRGs (Efroymson et al., 1996).

Equilibrium Partitioning (EqP) was also used to generate PRGs for some non-ionic organic contaminants. The EqP method allows the use of water-quality benchmarks to calculate sediment quality benchmarks, which can be used as PRGs. The formula to calculate these values also incorporates the total organic carbon (TOC) in the sediments and the organic carbon partition coefficient (K_{oc}), as follows:

$$SQB = foc * K_{oc} * WQB$$

where:

SQB = Sediment Quality Benchmark (for use as PRG)
foc = mass fraction of organic carbon in the sediments
K_{oc} = organic carbon partition coefficient
WQB = water quality benchmark

For the calculation of PRGs, Efroymson used a foc value of 1%, as recommended by EPA (EPA, 1996). WQB that were used to obtain PRGs using this method were, in order of preference, AWQC, LCVs for fish, daphnids, or other invertebrates, and SCVs. LCVs were not used if they were estimated from acute toxicity.

TABLE 7-3
SOIL AND SEDIMENT PRGs PROTECTIVE OF ECOLOGICAL RECEPTORS
AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs	SEDIMENT SAMPLE RESULTS RANGE	MAXIMUM BACKGROUND SEDIMENT LEVEL	SURFACE SOIL PRG PROTECIVE OF SEDIMENT		SEDIMENT PRG
INORGANICS (mg/kg)[2]			SITE 2	SITE 3	
Arsenic	2 - 14.05	2.8	77.1	91.1	42[1]
Barium	62.7 - 1,060	65.9	1600	1600	500[3]
Cadmium	0.2 - 8.4	-	7.69	9.08	4.2[1]
Chromium	13.7 - 224	11.7	531	531	160[1]
Cobalt	3.4 - 75.2	4.4	91.7	166	50[9]
Copper	13.5 - 136	8.2	202	238	110[1]
Lead	23.9 - 404	24.6	365	365	110[1]
Manganese	115 - 11,400	289	3650	3650	1,100[3]
Mercury	0.09 - 2.25	-	2.32	2.32	0.7[1]
Nickel	6.3 - 224	6.3	143	143	43[1]
Selenium	0.15 - 1.9	-	3.32	3.32	1.0[8]
Silver	0.8 - 2	-	3.32	3.92	1.8[1]
Zinc	61 - 8,435	3,889	895	895	270[1]
ORGANICS (µg/kg)					
1,2-Dichloroethene (total)	2 - 22	-	1690	2000	400[4]
2-Butanone	3 - 45	9	20,700	24,500	270[4]
2-Methylnapthalene	320	-	129	153	70[10]
4,4'-DDD	5 - 130	-	25.9	25.9	7.8[4]
4,4'-DDE	7 - 13	-	49.4	58.4	27[5]
4,4'-DDT	8.6 - 600	4.9	172	172	52[4]
4-Methylphenol	420 - 1,400	200	41.5	49.0	12[4]
Acenaphthene	44 - 3,500	-	164	194	89[1]
Acenaphthylene	100 - 270	-	239	283	130[1]

TABLE 7-3
SOIL AND SEDIMENT PRGs PROTECTIVE OF ECOLOGICAL RECEPTORS
AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs	SEDIMENT SAMPLE RESULTS RANGE	MAXIMUM BACKGROUND SEDIMENT LEVEL	SURFACE SOIL PRG PROTECTIVE OF SEDIMENT		SEDIMENT PRG
INORGANICS (mg/kg)[2]			SITE 2	SITE 3	
Acetone	108	-			9.1[1]
Anthracene	82 - 8,300	97	458	541	250[1]
Aroclor-1254	20 - 615	24	239,000	239,000	72,000[6]
Aroclor-1260	160 - 1,500	-	209,000	209,000	63,000[6]
Benzo(a)anthracene	390 - 20,000	380	2290	2290	690[1]
Benzo(a)pyrene	360 - 17,000	560	2520	2520	760[1]
Benzo(b)fluoranthene	540 - 25,000	830	5860	1060	3,200[10]
Benzo(g,h,i)perylene	290 - 13,000	370	1230	2220	670[10]
Benzo(k)fluoranthene	210 - 20,000	290	5860	1060	3,200
Bis(2-ethylhexyl)phthalate	210 - 7,900	-	4940	5840	2,700[1]
Butylbenzylphthalate	41 - 380	-	115	209	63[6]
Carbazole	61 - 5,700	240			NA[2]
Chrysene	390 - 24,000	590	2820	2820	850[1]
Dibenzo(a,h)anthracene	130 - 5,300	53	464	464	140[1]
Dibenzofuran	52 - 2,400	-	1390	1390	420[4]
Endosulfan II	3.8 - 11	-	18.2	18.2	5.5[4]
Fluoranthene	940 - 43,000	1,400	4970	4970	1,500[1]
Fluorene	63 - 5,900	47	464	464	140[1]

TABLE 7-3
SOIL AND SEDIMENT PRGs PROTECTIVE OF ECOLOGICAL RECEPTORS
AREA A SEDIMENT
NAWC WARMINSTER, PENNSYLVANIA

COCs	SEDIMENT SAMPLE RESULTS RANGE	MAXIMUM BACKGROUND SEDIMENT LEVEL	SURFACE SOIL PRG PROTECTIVE OF SEDIMENT		SEDIMENT PRG
INORGANICS (mg/kg)[2]			**SITE 2**	**SITE 3**	
Indeno(1,2,3-cd)pyrene	240 - 14,000	320	1110	1990	600[10]
Naphthalene	60 - 530	-	0.73	0.86	0.39[1]
Pyrene	680 - 40,000	760	4640	4640	1,400[1]
Tetrachloroethene	2 - 130	-	10,600	10,600	3,200[7]

A shaded cell indicates that the COC analytical results exceed the PRG protective of sediment.

(1) Cited in Efroymson et al. (1996); Probable Effects Level (PEL) from Florida Dept. Of Environmental Protection.
(2) No suitable PRG was available.
(3) Ontario Ministry of the Environmental (OME) Severe Effects Level (SEL) from OME, 1992.
(4) Chronic Value (SCV).
(5) Cited in Efroymson et al. (1996); Effects Range-Median (ER-M) value from NOAA.
(6) Cited in Efroymson et al. (1996); Calculated using Equilibrium Partitioning with Lowest Chronic Value (LCV) for fish.
(7) Cited in Efroymson et al. (1996); Calculated using Equilibrium Partitioning with Lowest Chronic Value (LCV) for daphnids.
(8) NOAA, 1994. NOAA Screening Guidelines for Organics and Inorganics, Quick Reference Cards, HAZMAT Report 94-8.
(9) MOE, 1993. Guidelines for the protection and Management of Aquatic Sediment Quality in Ontario, Ministry of Environment and Energy, Ontario, Canada (August).
(10) Region III BTAG Screening Levels (August 9, 1995)

Effects Range-Median (ER-M) values were also presented as PRGs by Efroymson et al. (1996). These are commonly referred to as the "NOAA" values (Long et al., 1995). Effects Range-Low (ER-L) and ER-M values were calculated by Long et al. (1995) by obtaining laboratory sediment toxicity data, modeling data, and effects data from field studies and ranking them in ascending order by toxic concentration for each contaminant. The lower 10th percentile and 50th percentile of the effects data for each contaminant were identified and designated as the ER-L and ER-M, respectively. ER-M values are defined as the concentrations above which "frequent" and below which "occasional" adverse effects are expected to be observed. The ER-L concentration is the level below which "infrequent" effects may be expected and are therefore potentially over protective for remedial goals. By setting the ER-M as a maximum value for remediation, the mean contaminant concentration following remediation will be within the range of "occasional" adverse effects, which is assumed to be acceptable. Therefore, ER-M values appear to be adequate for use as PRG values.

Sediment quality assessment guidelines presented by the FDEP were used to obtain sediment PRGs (FDEP, 1994). Similar to Long et al., FDEP guidelines were derived using toxicity information from a large, diverse database. FDEP utilized the expanded National Status and Trends Program (NSTP) database, which contains information from EqP modeling, laboratory-spiked sediment bioassays, and field investigations of sediment toxicity and benthic community composition. From this database, an effects data set (EDS) and no effects data set (NEDS) were developed and were each placed in ascending order of toxic contaminant concentration for each constituent. From these lists, a threshold effects level (TEL) and probable effects level (PEL) were calculated. The TEL is the square root of the 15th percentile of the effects data set multiplied by the 50th percentile of the no effects data set. The PEL is the square root of the 50th percentile of the effects data set multiplied by the 85th percentile in the no effects data set. Efroymson et al. used the PEL values as PRGs, presumably since the TEL is quite conservative and may be overprotective of benthic receptors.

In addition, Efroymson et al. obtained PRGs from Ontario Ministry of the Environment sediment quality guidelines (OME, 1992). OME presents Lowest Effect Levels (LEL) and Severe Effect Levels (SELs). The LEL is calculated for a contaminant by first plotting contaminant concentration versus the corresponding abundance of a given species from several studies to obtain a species screening level concentration (Species SLC). From this plot, the 90th percentile of the concentration distribution is determined. Then, the 90th percentiles for several species are plotted. The 5th percentile and 95th percentile of these concentrations are determined and represent the LEL and SEL, respectively. Due to the heavily conservative nature of the LEL, SEL values were used as PRGs by Efroymson et al. (1996).

If Efroymson et al. did not propose a PRG level for a sediment COC identified in the Phase III RI report, the benchmark toxicity value used in the RI report was identified as a tentative PRG . These PRG levels contain more uncertainty than the PRGs suggested by Efroymson et al. since they were not identified as PRGs by Efroymson.

It should be noted that none of the authors of individual benchmark sets discussed above has explicitly recommended the use of their benchmarks as PRGs. Efroymson et al. (PRGs) has suggested their use as remedial goals in lieu of widely accepted standard PRGs. Furthermore, Efroymson et al. preferentially used the lowest value among the sources used to obtain the PRGs. Hence, PRGs for some contaminants may be overly conservative and therefore overprotective of ecological receptors. None of the sediment PRG levels presented in Table 7-3 are site specific. Ideally, site-specific toxicity studies could be performed, and site-specific parameters should be used, to develop PRG levels that, due to their site-specific nature, would reduce the uncertainty in the PRG levels and reduce the probability that the PRG levels are overprotective. Overprotective PRG levels could result in unnecessary remediation of the sediment that could potentially result in more harm to aquatic ecological receptors than the contaminants present in the sediments.

7.3.2 Surface Soil PRGs for the Protection of Sediments

Surface soil PRGs are soil concentrations that are protective of the migration of residual surface soil contaminants to sediment. Surface soil PRGs were primarily developed through the use of a surface water runoff contaminant fate and transport model. The subset of chemicals considered for PRG evaluation consists of the ecological COCs identified for Area A sediments. The list of COCs was narrowed based on the following criteria:

- Ecological COCs found only in Area A surface soil were retained.
- Inorganic ecological COCs found below background concentrations were eliminated from the list of COCs. Organic ecological COCs, regardless of the concentration, were retained if detected in surface soil.

The sediment contaminant concentrations were estimated at the receptor locations (base property boundary) based on the assumed concentrations in the surface soil at various source locations. The assumed source concentration was then iteratively changed until the model predicted concentration at the exposure point was just below the acceptable PRG concentration. The final assumed source concentration is the surface soil PRG for the protection of sediments.

Table 7-3 illustrates the surface soil PRGs protective of sediments for Area A. For a derivation of these PRGs, refer to Appendix J, Development of Surface Soil Preliminary Remediation Goals. Among the post-removal surface soil PRGs for Sites 2 and 3, several PAH and metal results exceed these PRGs. For Site 2, the presence of a vegetated soil cover and drainage structure installed after the soil removal actions has greatly minimized the potential of any remaining Site 2 surface soil contaminants from migrating to the nearby stream via overland runoff.

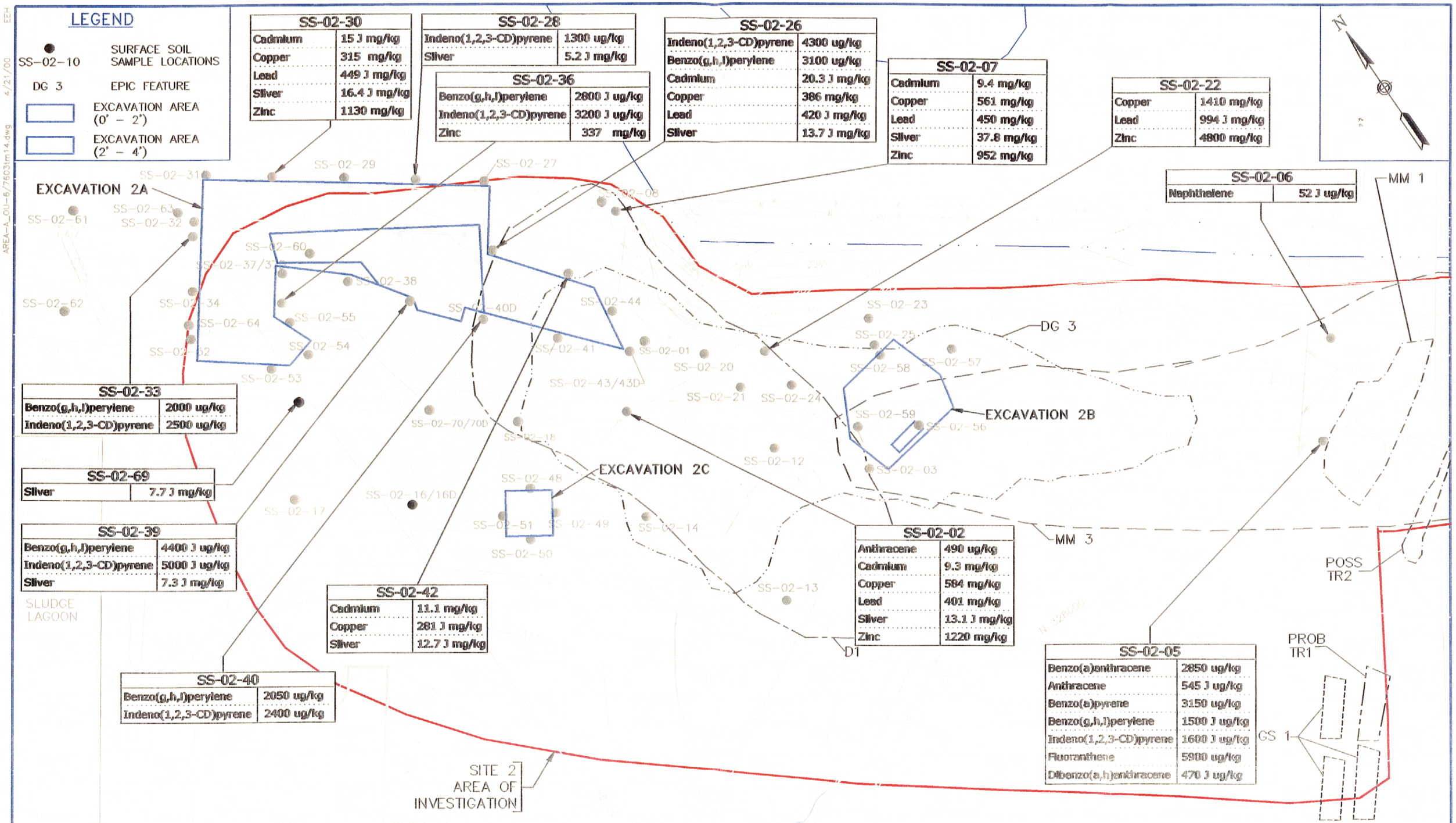
For Site 3, the presence of a vegetated slope between the site and the stream acts to inhibit the transport of soil contaminants to Area A sediment.

Figure 7-1 displays the sample locations and surface soil contaminant concentrations that exceed the soil PRGs protective of sediment. Conditions at Site 1 are not conducive to the migration of soil contaminants to Area A sediments (primarily due to the greater distance to the stream and surface topography). There were no exceedances of soil PRGs protective of sediment among the Site 1 and Site 3 surface soil samples.

In addition, the maximum sediment concentrations contained in Area A stream samples for the ecological COCs were generally greater than the respective post-removal surface soil maximum concentrations.

Exceptions for organic compounds were noted for 2-methylnapthalene, (320 ug/kg in sediment; 21,000 ug/kg in surface soil) acenaphthylene (270 ug/kg in sediment; 440 ug/kg in surface soil) and Aroclor-1254 (615 ug/kg in sediment; 3,700 ug/kg in surface soil) in Site 2 surface soils. For inorganic compounds contained in Site 2 surface soils, cadmium (8.4 mg/kg in sediment; 20.3 mg/kg in surface soil), copper (136 mg/kg in sediment; 1,410 mg/kg in surface soil), lead (404 mg/kg in sediment; 994J mg/kg in surface soil), and silver (2 mg/kg in sediment; 58.4 mg/kg in surface soil) maximum concentrations were greater than the highest sediment levels. Less than 10 percent of the Site 2 surface soil samples detected cadmium and lead levels greater than their sediment maximum concentrations. For copper and silver, the percentages were 18 and 33 percent, respectively. Thus, only a very small portion of Site 2 has the low potential to significantly affect future sediment quality. There were no exceptions for Site 3 surface soil and one exception for aluminum contained in Site 1 surface soil (15,650 mg/kg in sediment; 16,600 mg/kg in surface soil).

For these reasons, there is no apparent need to excavate or other aggressively remediate contaminated Area A surface soils to adequately protect stream sediment. and associated ecological receptors.



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REVISED BY	DATE
AS NOTED	

Tetra Tech NUS, Inc.

POST-REMOVAL SURFACE SOIL CONCENTRATIONS
SEDIMENT PRG EXCEEDANCES
AREA A – SITE 2
FORMER NAWC WARMINSTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. 7603
0601
APPROVED BY Jea DATE 11/10/00
FIGURE 7-1

442B32Y

7.4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Identification, screening, and evaluation of potentially applicable technologies and process options are steps in the FS process. The primary objective of this phase of the FS is to develop an appropriate range of remedial technologies and process options that will be formulated into preliminary remedial alternatives. Screening typically involves the following steps:

- Establish remedial action objectives (Section 7.2)
- Identify general response actions
- Identify and screen remedial technologies and process options
- Evaluate and select representative process options

As part of the abbreviated FS process, the more applicable technologies were screened and a representative process option was selected in order to streamline the development of alternatives for detailed evaluation. By using this approach, the general response actions by themselves were used to develop viable remedial alternatives.

7.4.1 General Response Actions

General response actions (GRAs) describe categories of actions that could be implemented to satisfy or address a component of a PRG for the site. Typically, the formation of remedial action alternatives represents the coupling of general response actions to fully address remedial action objectives. When implemented, the coupled GRAs are capable of achieving the PRGs, that have been generated for each contaminated medium at the site.

The following GRAs were considered for Area A sediment: and soils

- No action
- Environmental monitoring
- Containment
- Removal, treatment, and disposal

For Area A soils, the no action and institutional control GRAs were evaluated to meet applicable remedial action objectives.

7.4.1.1 No Action

The no-action response is retained throughout the FS process and provides a comparative baseline against which other alternatives can be evaluated. Under this response, no remedial action would be taken. In the no-action alternative, the contaminated media are considered to be left "as is," without the implementation of any institutional controls, containment, removal, treatment, or other mitigating actions.

7.4.1.2 Environmental Monitoring

Environmental monitoring would be conducted to ensure that hazardous substances are not migrating and to help assess potential effects on ecological receptors. The volume, mobility, and toxicity of the contaminants are not be reduced.

7.4.1.3 Institutional Controls

Institutional controls such as deed restrictions may be utilized to control construction and/or excavation activities that may disturb Area A soils in a manner which results in migration of Area A soil contaminants exceeding PRGs to the nearby stream. In addition, while residential use is not reasonably anticipated, institutional controls such as deed restrictions and zoning should be implemented to prevent residential land use.

7.4.1.4 Containment

Another method of reducing risk to the public and the environment is through containment, which involves the application of physical measures to reduce the potential for exposure to contaminants and/or contaminant migration. To reduce the migration of contaminants, the contaminated media must be isolated from the primary transport mechanisms, such as wind, erosion, surface water, and groundwater. Contaminated media may be isolated by installing surface and subsurface barriers that either block or divert transport media (e.g., groundwater, wind) or exposure pathway from the contaminants.

7.4.1.5 Removal, Treatment, and Disposal

Technologies under the removal response action category are used to move contaminated media from their present location in order to be treated and/or disposed elsewhere. Removal process options are combined with treatment and/or disposal process options to develop alternatives.

The treatment response action includes treatment process options (both in situ and ex situ) and physical, chemical, biological and/or thermal measures designed to reduce the toxicity, mobility, and/or volume of the contaminants present. The treatment process options are used with removal and disposal process options to develop alternatives.

Disposal technologies include placement of removed or treated materials in an on-base or off-base disposal facility. The toxicity, mobility, or volume of the contaminants is not reduced through the singular application of disposal. This response action will reduce or eliminate exposure pathways related to direct contact with contaminated sediment.

7.4.2 Screening of Technologies and Process Options

The evaluation criteria for detailed screening are effectiveness, implementability, and cost. The following are descriptions of the evaluation criteria:

- Effectiveness
  - Protection of human health and environment; reduction in toxicity, mobility, and volume; and permanence of solution.
  - Ability of the technology to address the estimated areas or volumes of contaminated medium.
  - Ability of the technology to meet the remediation goals identified in the remedial action objectives.
  - Technical reliability (innovative versus well-proven) with respect to contaminants and site conditions.

- Implementability
  - Overall technical feasibility at the site.
  - Availability of vendors, mobile units, storage and disposal services, etc.
  - Administrative feasibility.
  - Special long-term maintenance and operation requirements.

- Cost (Qualitative)
  - Capital cost.

- Operation and maintenance (O&M) costs.

Screening evaluations at this stage generally focus on effectiveness and implementability, with less emphasis on cost evaluations. Technologies whose use would be precluded by waste characteristics and inapplicability under the given site conditions are screened and eliminated from further consideration. At this stage, no technologies will be eliminated based on cost. Each technology presented in this section is not necessarily intended to be implemented alone, as it may be combined with other technologies into remedial action alternatives.

7.4.2.1 No Action

The no-action alternative consists of maintaining the status quo at the site. No action is retained as a baseline for comparison purposes.

Effectiveness: No action would not be effective in meeting the preliminary remediation goals for the site or the remedial action objectives for contaminated soils.. Potential exposure to contaminated sediments and soils could pose an unacceptable level of health hazard to current and future receptors.

Implementability: There are no implementability concerns.

Cost: There are no costs associated with the no-action alternative.

Conclusion: The no-action alternative is retained as required by the NCP to provide a baseline comparison.

7.4.2.2 Environmental Monitoring

Monitoring may consist of collection of environmental samples such as surface water, leachate, sediment, and biological, followed by analysis for target contaminants.

Effectiveness: Sampling and analysis of environmental media by themselves are ineffective in minimizing the migration of contaminants in the environment, but they can assess the migration of contaminants. In particular, they can be used to determine if actual migration of contaminants is occurring or if natural attenuation is occurring. Sampling and analysis of environmental samples would also be required to assess the progress and ensure completion of any future response actions at Area A.

Implementability: Monitoring is readily implementable. There are no significant technical or administrative difficulties.

Cost: Costs associated with sampling and analysis are low.

Conclusion: Retain environmental monitoring as a viable remedial alternative for Area A sediment. Compared to Alternative 1, monitoring provides added protectiveness over either a short- or long-term period for little additional cost.

7.4.2.3 Institutional Controls

Institutional controls can be used to limit land use and activities which expose contaminated soils to migration pathways. Prohibitions on excavation and other construction work without adequate safeguards (e.g., erosion and sedimentation control plans) would greatly reduce contaminant migration from surface soils into Area A sediment.

Effectiveness: Institutional measures such as fencing, security, and future land use restrictions would reduce the opportunity for exposing contaminated soils to surface runoff. Control of any access restrictions (e.g., fencing and gates) would need to be enforced by the new property owner and may not be very effective in the long term. These measures would also be effective in preventing the erosion and migration of contaminants from Site 2 and 3 surface soils to the nearby stream, thus protecting ecological receptors from any adverse effects that may result from additional contaminant loading.

Implementability: Institutional controls would be imposed by deed restrictions, covenants, or zoning restrictions to eliminate or limit human exposure of contaminated Area A soils. Land use restrictions would prohibit residential use over surface and subsurface soils. The metes and bounds of Area A would be surveyed and recorded in the appropriate property deed(s). The deed will become the legal document included during all subsequent property transfer actions. Records on the presence, nature, and extent of contamination would be maintained to ensure that adequate measures are implemented in the future to minimize exposure to contaminants. Every 5 years, a review will be conducted by the Navy and EPA to evaluate the status of Area A and determine whether further action is warranted.

Cost: Costs associated with institutional controls are minor, primarily consisting of administrative costs to process property transfer documents and to perform 5-year reviews.

Conclusion: Retain the use of institutional controls to enforce access and land use restrictions with regard to contaminated Area A soils and to protect Area A sediment and associated ecological receptors from any site disturbances.

7.4.2.4 Containment

The technologies being considered under containment are surface water controls. Surface water controls consist of the use of stream diversion or other erosion control measures. Stream diversion involves the construction of channels, dikes, or berms to provide a preferential pathway for surface water, collected from rainfall, to run off. Such preferential pathways minimize contact with the surface soils and consequently reduce the migration of contaminants from the surface soils into the environment. Other erosion control measures consist of vegetative cover and/or rip-rap (i.e., rocks, stones, etc.) placed over the contaminated area and a topsoil cover to minimize the entrainment of contaminated material or clean soil (cap material) in surface water runoff. Vegetation is usually seeded in a topsoil covering the wastes, whereas rip-rap material is used on the surface of the soil.

Sediment traps also fall within the category of surface water controls. The purpose of such measures is to prevent suspended solids in surface runoff from discharging to nearby waterways. In typical sediment trap designs, surface runoff is diverted to a retention pond that facilitates the settling of suspended solids. Water is then slowly discharged to a natural waterway. Sediment traps require periodic maintenance consisting of the removal of settled suspended solids.

Effectiveness: Given a large volume of rainfall or overland runoff, surface water controls might be effective in the collection of rainfall and diversion of surface water flow. Such measures would mitigate erosion and the migration of contaminants from surface soil to the environment. The main concern with the effectiveness of erosion controls is to ensure that the integrity of such controls is maintained by preventing natural and human interference. Because the ownership of the base would change under the BRAC Program, responsibility for this maintenance would need to be assigned to the new owner.

Erosion control measures have already been implemented at Site 2 to minimize the overland runoff of water and suspended materials (such as soils) to the nearby tributary to Little Neshaminy Creek. These controls consist of a concrete berm and rip-rap to protect extraction well locations, increase the infiltration of rainfall and overland runoff into the ground, and divert any remaining runoff to a specific location. Combined with the 1998 Site 2 removal actions to excavate and dispose of contaminated surface and subsurface soils at three separate locations, the need for additional surface water control measures at Site 2 is not warranted. The largest removal action at Site 2 was immediately adjacent to the base property line and upgradient of the nearby tributary that flows near this boundary.

For Site 3, the 1998 removal action addressed the excavation and disposal of contaminated surface soils adjacent to Jacksonville Road and extended to about 30 feet from the nearby tributary.

Implementability: The construction of simple surface water controls can be implemented. Such controls require the selection of an appropriate discharge location into a storm sewer or surface water body so that hydraulic capacities are not exceeded. Erosion control measures have already been implemented at Site 2 to minimize the overland runoff of water and suspended materials (such as soils) to the nearby tributary to Little Neshaminy Creek.

The construction of sediment traps and stream diversion measures is more complex for the Area A stream, given the small size of the waterway, relatively steep embankments along both sides of the stream, and difficulty in accessing the stream due to mature vegetation and the slopes themselves. The portion of the stream within the base property is channeled with a very high (10 to 12 feet) and steeply sloped (4:1 to 5:1) southern bank. The stream channel averages about 4 feet in width and 0.5-foot in depth. The long-term periodic maintenance of sediment traps or stream diversion channels also limits the effective implementation of these techniques.

Cost: Construction of surface water channels and erosion controls are low to moderate, depending on the complexity of the controls selected.

Conclusion: Eliminate the use of surface water controls as a potential means of reducing the migration of contaminated material into the environment. The more complex surface water controls (specifically sediment traps and stream diversion measures) will not be evaluated due to implementability concerns.

7.4.2.5 Removal, Treatment, and Disposal

Dredging is one type of removal alternative that is applicable to removing sediments from the unnamed tributary adjacent to Area A. Clamshells, draglines, or similar equipment can perform dredging. The type of equipment that is selected must take into consideration several factors, such as type of material, load-supporting ability of the soil, rate of required excavation, depth of excavation, etc. Usually power shovels, draglines, clamshells, or backhoes are used for deep excavation and/or when required excavation rates are high. These types of equipment are typically mounted on mobile units and operated hydraulically.

The logistics of dredging must take into account the available space for operating the equipment and loading/unloading to transport the removed material. Additionally, other location factors such as the presence

of electric, sewage, and other utility lines must also be considered. After contaminated sediment is removed, the excavated location is filled and graded with clean fill material or treated soils.

CERCLA includes a statutory preference for treatment of site contaminants that pose a principal threat. This would be coupled with dredging. For purposes of this FS, chemical fixation was selected as the representative treatment process. Other processes, such as thermal desorption, incineration, and vitrification, were also briefly considered, but were dismissed as part of the streamlined FS process for this report.

Off-base disposal entails transport of excavated sediment to an off-base disposal facility. A permitted treatment, storage, and disposal (TSD) facility would be required for any hazardous waste, as defined by RCRA. In addition, land disposal restrictions currently require that most wastes be treated to render them nonhazardous prior to disposal. A permitted, solid waste disposal facility would be used for all nonhazardous waste, as defined by RCRA.

On-base disposal was ruled out due to property transfer issues. The availability of adequate clean land area at the base is an important consideration for the implementation of a disposal cell because of the impact on future land use. Potentially, deed restrictions would be required on any site where wastes are allowed to remain with or without treatment. On-base disposal could be difficult to implement due to future land use considerations.

Effectiveness: Dredging would be effective in removing existing or historical contaminated sediment from the stream because it is applicable to the complete range of contaminant groups with no particular target group. The volume of contaminated sediment does not prohibit the use of such measures. Confirmatory sampling is required to indicate the completion of the removal action. Samples must be taken from the exposed faces of the dredged area and analyzed for the contaminants of concern to ensure that the residual material is not contaminated at unacceptable levels.

In general, the Area A streambed is rocky and gravelly, while the few deeper (1 to 2-foot depths) and slower moving ponds within that portion of the stream near Sites 2 and 3 contain a layer of finer sediment. Grain size analysis for Area A sediment samples indicated that sediments adjacent to Sites 2 and 3 were predominantly sandy and sediments slightly downstream of Area A were sandy to silty. These types of substrates tend to have fewer binding sites for contaminants than finer silty to clayey sediments. Due to these reasons, the amount of contaminated sediment that could effectively be dredged appears to be quite limited. Dredging may also facilitate the release of any existing contaminated sediment into more downstream portions of the Area A stream. In addition, dredging by itself will not be effective in eliminating

the opportunity for future sediments to become contaminated, since the transport processes (e.g., runoff from roadways and parking lots; potential groundwater discharges to the stream; overland runoff of rainfall and suspended material; and stormwater outfalls) related to potential stream contamination will not be addressed.

As discussed in Section 7.4.2.4, the removal actions (including the installation of erosion control measures at Site 2) at Sites 2 and 3 have already addressed a majority of the contaminated surface soils that could erode and subsequently transport residual contaminants to the nearby stream. As such, the potential for significant additional contaminant sediment loading due to surface soil migration in the future is low.

Chemical fixation is a viable option for contaminated sediments located at NAWC Warminster and should be effective in solidifying the sediment matrix and immobilizing inorganic and organic contaminants found in Area A sediment. Fixation would only be required for sediment determined to be hazardous, as needed to comply with land disposal restrictions. Implementation should not cause any adverse effects on human health and the environment. Nonhazardous sediment would be disposed in a Subtitle D landfill.

The disadvantages to this process are as follows: Solidification will minimize migration of these contaminants; however, long-term stability and leachability are potential concerns because the contaminants are not destroyed but remain within the solidified mass.

Off-base disposal at a landfill is effective because all contaminated sediment would be taken away and no residual risks would remain. Landfills are effective at isolating wastes from the environment. The waste-specific requirements vary from state to state and by individual landfills. The selection is based on waste-specific effectiveness, permitting, and cost considerations.

Implementability: Dredging is implementable. Equipment is readily available and the technology is proven and established in the construction/remediation industry. However, CERCLA includes a statutory preference for treatment of site contaminants that pose a principal threat, and excavation and off-site disposal are now less acceptable than in the past. During excavation, OSHA requirements must be met to ensure that the exposure of the workers to potential COCs is minimized. Dredging may require the use of temporary containment measures to minimize release of contaminated sediments into other portions of the Area A stream.

Similar to the implementability of more complex surface water controls, dredging will be relatively complicated due to accessibility concerns (e.g., narrow stream channel, steep embankments, and presence of mature vegetation, including trees). While the technologies available for dredging are implementable, they have one or more significant disadvantages with regard to Area A sediment. The

more common technologies include in-stream mechanical dredging and low-turbidity hydraulic dredging. The small size of the stream, the limited amount of significant sediment deposits, and the potential need to dewater dredged materials and revegetate any damaged wetlands, further limits the ability to adequately perform this type of work.

Chemical fixation is implementable. Sediments would need to be dewatered prior to treatment. Monitoring for physical integrity of the treated material and the effectiveness of the process is typically required. The equipment and resources necessary to solidify the soil and waste/fill material on site are readily available, with several vendors capable of performing this work. The equipment necessary for this process is similar to that used for cement mixing and handling. It includes a feed system, mixing vessel, and a curing area, a bulk storage area for the solidification agents, and trucks to transport cured material to a land disposal area. Fixation is performed at TSD facilities prior to land disposal. Several TSD facilities are available and can potentially accept the contaminated sediment from the Area A stream. The most cost-effective type of required treatment would ultimately be determined by the TSD facility. To clearly evaluate the effectiveness of the remedial technology, a treatability study would be required.

Off-base landfilling of soil wastes is implementable. Permitting requirements vary based on the particular state and landfill. In general, the more protective a landfill is, the easier it is to obtain waste approval. The chemical properties of the wastes are also a factor. Another common requirement for landfilling is the absence of free water in the waste. Dewatering sediments would be required before disposal.

Cost: Dredging costs are directly proportional to the extent of excavation required but are typically low to moderate. Dredging costs also depend upon the accessibility of the sediments. Capital and O&M costs are moderate for chemical fixation. It is anticipated that only materials classified as RCRA-hazardous waste would require treatment. An environmental monitoring program would also be required to verify the completeness of the dredging work, to assess the long-term effectiveness of the removal, and to determine the impact, if any, of future operations at the base on the unnamed tributary to Little Neshaminy Creek.

The cost of off-base landfilling is highly variable, ranging from low to high for nonhazardous and hazardous waste landfills, respectively.

Conclusion: Eliminate dredging, treatment, and disposal of contaminated sediment due to the limited effectiveness of dredging itself and implementability concerns regarding accessibility and unfavorable stream conditions.

7.4.3 Summary of Screening and Selection of Process Options

As a result of the screening process, the following technologies have been retained and are summarized as follows.

General Response Action	Remedial Technology	Process Options
No Action	None	None
Monitoring	Environmental Monitoring	Stream and Sediment Sampling and Analysis
Institutional Controls	Use Restrictions	Deed Restrictions and Covenants; Local Ordinances

7.5 ANALYSIS OF ALTERNATIVES

The technologies and representative process options that passed the screening step were evaluated with regard to the reasonably anticipated land use exposure scenarios, and accommodation of PRGs and ARARs. Although the ownership of the base has been transferred from the Navy to the Federal Lands Reuse Authority (FLRA), it is anticipated that Area A will remain an industrial area in the future, based on the future land use plan for the base. Remedial alternatives for Area A soils and sediment were developed for the industrial land use scenario. Two alternatives were evaluated:

1. No Action
2. Institutional Controls and Environmental Monitoring

In general, remedial alternatives should be developed to achieve compliance with ARARs and PRGs. However, in certain cases, technical limitations and cost prevent development of alternatives that comply with all ARARs and PRGs. For example, waste areas that pose relatively low levels of risk over long time frames are considered appropriate for containment technologies (e.g., capping) when combined with institutional controls.

In cases where background levels of an inorganic COC exceed the most stringent PRG for a given risk level and land-use scenario, the background concentration of the COC was used as the remedial standard.

7.5.1 Criteria for Detailed Analysis

The following nine criteria were used for the detailed analysis for each remedial alternative:

1. Overall protection of human health and the environment
2. Compliance with ARARs and TBCs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, and volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State and EPA acceptance
9. Community acceptance

The first seven criteria are specifically addressed in this FS. State and EPA acceptance will be evaluated after the State and EPA Region III have reviewed and commented on the draft FS report. Community acceptance will be addressed in the Record of Decision that will be finalized after the public comment period for the FS and Proposed Plan. State, EPA, and community acceptance must be considered during remedy selection.

7.5.2 Alternative 1: No Action

No action is required for this alternative. This alternative is required by the NCP and is used as a baseline comparison with other alternatives.

Overall Protection of Human Health and the Environment

Alternative 1 may not be protective of ecological receptors. The potential for inorganic, semivolatile organics and PCB contaminants in the sediment to pose potential risks to ecological receptors would continue to exist. However, none of the authors of individual benchmark sets presented in Table 7-3 has explicitly recommended the use of their benchmarks as PRGs. In the absence of regulatory criteria for ecological protection or site-specific toxicity tests, these benchmarks have been used as PRGs.

Compliance with ARARs and TBCs

Alternative 1 will not comply with ecological TBC benchmarks for inorganic, semivolatile organic, and PCB contaminants; however, these TBCs have not been explicitly recommended for use as PRGs and may be overly conservative in regards to estimating the risks posed to the tributary's flora and fauna.

Long-Term Effectiveness and Permanence

This alternative may not be effective in the long-term or permanently. The potential risk to ecological receptors would remain and Area A soil contaminants may migrate to the stream. Under this alternative, there are no construction or excavation controls for the Area A sites. Also, there would be no long-term monitoring programs to assess the potential migration of contaminants from the site.

Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 1 does not include treatment to reduce toxicity, mobility, or volume of the contaminants in the sediment. There are no treatment processes employed, and therefore no substances are treated or destroyed.

Short-Term Effectiveness

Since remedial actions would not occur, Alternative 1 would not pose risks to the local community or on-base workers during implementation and there would be no environmental impacts from implementation. However, none of the ecological PRGs would be achieved.

Implementability

Implementability is not applicable because actions would not occur.

Cost

There are no costs associated with the no-action alternative.

7.5.3 Alternative 2: Institutional Controls and Environmental Monitoring

This alternative consists of institutional controls and environmental monitoring.

The institutional controls would consist of deed restrictions which would control construction and/or excavation activities that may disturb Area A soils in a manner which results in migration of Area A soil contaminants exceeding PRGs to the nearby stream. In addition, while residential use is not reasonably anticipated, institutional controls such as deed restrictions and zoning should be implemented to prevent residential land use.

Environmental monitoring would consist of periodic sampling to characterize surface water and sediment and to evaluate the resulting data. The purpose of the sampling would be to assess the extent of any contaminant loading to the stream, to assess the ecological effects of such loading, and to determine whether actions are needed based on these assessments.

Surface water, sediment, and biological samples (e.g., benthic macroinvertebrates) would be sampled on a periodic basis to assess the level of contaminants over time. Benthic organisms (e.g., periphyton, flatworms, insects, snails, midges) live on or at the bottom (i.e., not in the water column) of water bodies for most of their adult life cycle. Stream flow and other physical measurements (e.g., dissolved oxygen, turbidity, and pH) would also be recorded. The objectives of the monitoring program would be to establish baseline chemical and biological conditions of the Area A stream and to determine if stream conditions vary over time. The monitoring program would identify any impacts on the stream, help determine the cause of any impacts and the nature of any necessary actions help determine the cause of any actual or potential impacts to the stream and related ecological receptors. If necessary, modifications to the monitoring program would be made to further define or quantify the extent of these impacts and to identify possible causes of the contamination.

Toxicity testing would be performed on Area A sediment, if needed. The scope of this testing would be to determine the bioavailability of sediment contaminants in the tributary by evaluating the chronic toxicity of sediments in controlled laboratory tests. The test would consist of exposing an ecological receptor to tributary sediments over a 10-day period and monitoring the survival and growth of the test organism over this period. The methods of this test are described in detail in EPA's Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater (EPA, 1994c). The results of this test would provide a better understanding of the risks posed by contaminants in the sediment to ecological receptors.

For costing purposes, it is assumed that monitoring would be performed for 5 years. Surface water, sediment, and benthic macroinvertebrates would be sampled quarterly for the first year, semiannually for the second year, and annually for the next three years. A 5-year review would take place at the end of the

initial monitoring program to evaluate the stream and determine whether further action is necessary. The review would be required because this alternative allows contaminants to remain at concentrations that exceed sediment PRGs. The review will support the scope of any additional environmental monitoring or termination of the monitoring program altogether.

Alternative 2 also consists of implementing institutional controls to prevent construction or excavation activities that may mobilize Area A soil contaminants to the stream. Land use restrictions would preclude residential land use in Area A. Construction/excavation restrictions or controls would be imposed by deed restrictions, covenants, or zoning restrictions. Records of the presence, nature, and extent of soil contamination would be maintained to ensure adequate measures are implemented in the future to minimize exposure. Every 5 years, a review would be conducted by the Navy and EPA to evaluate the sites and determine whether further action is warranted. Periodic reviews would also be required since this alternative allows contaminants to remain at unacceptable concentrations for residential property use.

Overall Protection of Human Health and the Environment

Compared to Alternative 1, Alternative 2 is protective of ecological receptors. In addition, given the limitations of all other technologies and process options for protecting ecological receptors from potential risks associated with sediment contamination, including containment (e.g., surface water controls) and removal of the sediments of concern (e.g., dredging), no other remedial alternative offers a more effective and implementable solution to ensure the protection of aquatic and terrestrial ecosystems. The potential for inorganic, semivolatile organics, and PCB contaminants in the sediment to pose risks to ecological receptors would continue to exist; however, these risks are uncertain. This alternative is protective of human health by limiting the potential for exposure to soil contaminants through land use restrictions. Inspections and reviews would ensure restrictions are effectively enforced.

Compliance with ARARs and TBCs

Alternative 2 does not propose active treatment of contaminated sediment within the tributary; therefore, it does not comply with ecological TBC criteria. However, none of the authors of individual benchmark sets presented in Table 7-3 has explicitly recommended the use of their benchmarks as PRGs, and the use of these values may be overprotective. Institutional controls would achieve the primary remedial action objective for Area A soil contaminants which is to migration to surface water.

Long-Term Effectiveness and Permanence

Alternative 2 may not be effective in the long term because it is uncertain whether other on-base and off-base sources are contributing to contaminant loading of the sediment. Even if Alternative 2 is coupled with institutional controls for Area A soils, concentrations of COCs in sediment may increase over time due to contribution from other sources. However, contribution by these uncharacterized sources may not be significant and contamination may attenuate over time. Institutional controls would prevent or limit migration of soil contaminants by controlling intrusive activities such as excavation. The degree of effectiveness for the institutional controls would depend of the reliability and enforcement of these measures.

Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2 does not include treatment to reduce toxicity, mobility, or volume of the contaminated media at the site. There are no treatment processes employed, and therefore no materials are treated or destroyed.

Short-Term Effectiveness

Alternative 2 would have minimal short-term effectiveness concerns. Any exposure of workers to sediment during monitoring would be minimized by the use of personal protective equipment (PPE). There would be no immediate risks to the community or environmental impacts upon implementation of the monitoring program. Institutional controls would not pose short-term risks to human health, however, it is anticipated that the development of deed restrictions and other administrative controls may take up to 6 months to place into effect.

Implementability

Implementability concerns associated with Alternative 2 are expected to be minimal. Monitoring activities could be implemented immediately. Prior to property transfer, the Navy would be required to prepare a finding of suitability to transfer (FOST) for the property and then a deed. Appropriate deed restrictions/ covenants, including those necessary to control excavation activities or procedures for soil excavation work, would be addressed during the preparation of both the FOST and deed. The implementation of these restrictions is administratively possible through Navy legal actions. The Navy would retain the primary responsibility to conduct 5-year reviews for the property, assisted by EPA as required by law.

Cost

The estimated costs for this alternative are:

- Estimated capital costs for institutional controls: $20,000
- Estimated capital costs for environmental monitoring: $21,483
- Estimated O&M costs for Year 1 of environmental monitoring: $100,474
- Estimated O&M costs for Years 2 through 5 of environmental monitoring: $143,746
- Estimated costs for 5-year review: $12,000
- Estimated 30-year present worth: $275,360

The present-worth cost estimate of this alternative is based on a 5-year operation period for the monitoring of surface water, sediment, and benthic macroinvertebrates. Sampling would be conducted quarterly for the first year, semiannually for the second year, and annually for the next 3 years. Toxicity testing is not included for the environmental monitoring program. The details of the cost estimations are provided in Appendix K.

7.6 COMPARATIVE ANALYSIS OF ALTERNATIVES

The remedial alternatives were compared using the same criteria used in the previous section.

7.6.1 Overall Protection of Human Health and the Environment

The main concern addressed in this section is the protection of ecological receptors from adverse effects from contact with Area A sediment. Alternative 1 is not protective of the environment. Actions are not conducted that limit migration of soil contaminants that exceed sediment PRGs for the protection of aquatic and terrestrial receptors.

Alternative 2 is protective by limiting the migration of soil contaminants to the nearby stream. This alternative provides long-term monitoring to evaluate stream conditions in the event that these conditions significantly change over time. If necessary, modifications to the monitoring program would be made to further define or quantify any actual or potential impacts to the stream and related ecological receptors. Therefore, Alternative 2 provides a greater measure of protectiveness for ecological receptors than Alternative 1.

7.6.2 Compliance with ARARs AND TBCs

The concerns addressed in this section are compliance with chemical-specific, location-specific, and action-specific ARARs and TBCs. Alternative 1 does not comply with chemical-specific ARARs and TBCs

regarding sediment for protection of ecological receptors. For Alternative 2, contaminants remain in sediment at concentrations that exceed TBCs. However, these TBCs may be overly conservative estimates of the risks posed to ecological receptors. Since no aggressive remedial action (e.g., excavation and disposal) would be taken under these alternatives for contaminated soils, there are no ARARs or TBCs.

7.6.3 Long-Term Effectiveness

The main concerns in this category are the reliability of controls over the residual risks associated with untreated contaminants at the site and the permanence of the effectiveness of each alternative.

Alternative 1 is not effective in the long term because it does not involve controls and allows residual risk associated with sediment to remain uncontrolled. Both alternatives do not provide measures to mitigate the possible contamination of sediment from uncharacterized sources.

Alternative 2 provides for the management of risks associated with Area A soils through institutional controls. The effectiveness of these controls depends on their reliability and continued enforcement. Deed restrictions are an effective option for prohibiting certain type of land uses since these restrictions are inherently part of the property transfer process, regardless of the status of property ownership.

7.6.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The major concerns addressed are reduction in toxicity, reduction in mobility, and reduction in volume of contaminants.

Alternatives 1 and 2 do not reduce the toxicity and volume of ecological COCs in media of concern. However, technologies that reduce the toxicity and volume of metals, a major category of COCs found in Area A sediment, are not readily available. These alternatives also do not reduce the mobility or COCs in media of concern.

7.6.5 Short-Term Effectiveness

The main concern is potential effects to the workers, community, and ecological receptors during remedial action. This criterion is not relevant to Alternative 1, where no action is involved.

Alternative 2 would be effective over the short-term period to monitor the overall quality of Area A sediments and the Area A stream in general. Periodic monitoring would ensure that sediments are not adversely impacted by either sources of hazardous substance contamination (e.g., Sites 2 and 3) or by urban runoff.

Along with institutional controls, these activities do not pose short-term risks to human health and the environment. The stream monitoring results could be used to evaluate another type of remedial alternative for the unnamed tributary, if warranted..

7.6.6 Implementability

The major concerns in this category consist of the ease of implementation, including availability of equipment and services, the technical complexity of the processes, and the ease of obtaining permits. This criterion is not applicable to Alternative 1. Alternative 2 is readily implementable.

7.6.7 Costs

The capital, operation and maintenance (O&M), and present-worth costs are presented as follows.

Alternative	Capital Cost ($)	O&M Cost Year 1 ($/Year)	O&M Cost Years 2 - 5 ($/Year)	30-Year Present Worth Cost (millions of $)
1	N/A	N/A	N/A	N/A
2	41,483	100,474	143,746	275,360[1]

Note:

[1] Includes estimated costs ($12,000) for one 5-year review.

REFERENCES

Army Corps of Engineers, 1987. Wetlands Delineation Manual. Technical Report Y-87-1. U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

ATSDR, 1989. Preliminary Health Assessment for U.S. Naval Air Development Center, Warminster, Pennsylvania. Atlanta, Georgia.

Barnthouse, L. W., G. W. Suter, S. M. Bartell, J. J. Beauchamp, R. H. Gardner, E. Linder, R. V. O'Neill, and A. E. Rosen, 1986. User's Manual for Ecological Risk Assessment. Environmental Sciences Division Publication No. 2679. Oak Ridge National Laboratory, Oak Ridge, TN.

BCW, 1992. Support Services in Association with the Closure of Lagoon No. 2, Concrete Sampling and Engineering Certification for NAWC Warminster, Pennsylvania. Reading, Pennsylvania. January 24.

Brown & Root Environmental (B&R Environmental), 1996a. Draft Phase III Remedial Investigation Report, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. November.

B&R Environmental, 1996b. Site 6 Removal Evaluation Report for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania.

B&R Environmental, 1996c. Interim Remedial Investigation Report for Operable Unit 4, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. October.

B&R Environmental, 1996d. Focused Feasibility Study Report for Operable Unit 4, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. October.

B&R Environmental, 1998a. Removal Site Evaluation for Area A Soils (Draft), NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. April.

B&R Environmental, 1998b. Results from Additional Site 1 Soil Investigation, Phase III RI/FS, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. July 10.

B&R Environmental, 1998c. Supplemental Subsurface Soils at Site 3, NAWC Warminster, Pennsylvania. King of Prussia, Penssylvania. July 23.

B&R Environmental, 1998d. Results from Additional Site 2 Surface Soil Investigation, Phase III RI/FS, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. July 28.

Calabrese, E. J., and L. A. Baldwin, 1993. Performing Ecological Risk Assessments. Lewis Publishers. Chelsea, Michigan.

Cowardin, L., V. Carter, F. Golet, and E. LaRoe, 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. Washington, DC.

EA Engineering, Science, and Technology, Incorporated (EA), 1995. Base-Wide Environmental Baseline Survey for NAWC Warminster, Aircraft Division, Warminster, Pennsylvania. Berkley Heights, New Jersey. March.

EA, 1999. Phase III Environmental Baseline Survey for NAWC Warminster, Pennsylvania. Berkley Heights, New Jersey. May.

EA, 2000. Storage Tank Report for NAWC Warminster, Aircraft Division, Warminster, Pennsylvania. Iselin, New Jersey. January.

Earth Technology Corporation, 1985. Well Profile Studies for Wells Nos. 4 and 5 and Well Profile Studies for Wells Nos. 1 and 2 at NADC Warminster, Pennsylvania. Somerset, New Jersey.

Environmental Photographic Interpretation Center (EPIC), 1994. Aerial Photographic Support, NAWC Warminster, Pennsylvania. Warrenton, Virginia.

Environmental Protection Agency (EPA), 1982. Aquatic Fate Process Data for Organic Priority Pollutants. EPA/440/4-81/014, Office of Drinking Water Regulations and Standards. Washington, DC. December.

EPA, 1986a. Quality Criteria for Water 1986. EPA 440/5-86-001. Office of Water Regulations and Standards. Washington, DC 20460.

EPA, 1989a. Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (Part A). EPA 540/1-89/002. Office of Emergencey and Remedial Response. Washington, DC.

EPA, 1989b. Guidance Document on the Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Interim Final Guidance. EPA 530/SW-89-026. Office of Solid Waste. Washington,DC.

EPA, 1992a. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities; Addendum to Interim Final Guidance. Office of Solid Waste Permits and State Programs Division. Wasington, DC. July.

EPA, 1992b. Methods for Evaluating the Attainment of Cleanup Standards. Volume 3: Reference-Based Standards for Soils and Solid Media. Office of Policy, Planning, and Evaluation. Washington, DC.

EPA, 1992e. Dermal Exposure Assessment: Principles and Applications. Interim Report. EPA 600/8-91/011/B. Office of Health and Environmental Assessment. Washington, DC. January.

EPA, 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive 9355.4-12. Washington, DC.

EPA, 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. EPA/540/R-93/081. Office of Emergency and Remedial Response. Washington, D.C. February.

EPA, 1995b. Draft EPA Region III BTAG Screening Levels. Philadelphia, Pennsylvania. August 9.

EPA, 1996a. Guidance for Data Quality Assessment. Pre-Publication Copy. Final. EPA QA/G-9. Quality Assurance Division. Washington, DC. February.

EPA, 1996a. Soil Screening Guidance. EPA/540/R-96/018. Office of Emergency and Remedial Response. Washington, DC. April.

EPA, 1999b. EPA Region III Risk- Based Concentration (RBC) Tables. Philadelphia, Pennsylvania. April 15.

Ernst and Young Real Estate Group, 1998. Economic Development Conveyance Application Plan for NAWC Warminster. Philadelphia, Pennsylvania. April.

Federal Land Reuse Authority (FLRA), 1999. Personal Communication between Neil Teamerson, Tetra Tech NUS, and Steve Rockwell, FLRA. April 30.

Foster Wheeler Environmental Corporation (Foster Wheeler), 1999. Draft Final Contractor's Close-Out Report for Removal of Contaminated Soil at Area A (Sites 1, 2 and 3), NAWC Warminster, Pennsylvania. Langhorne, Pennsylvania. September.

Halliburton NUS Corporation (HNUS), 1992. Draft Phase II Remedial Investigation Report for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. November.

HNUS, 1993a. Phase II Remedial Investigation Report for Operable Unit 1, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. April.

HNUS, 1993b. Focused Feasibility Study Report for Operable Unit 1, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. April.

HNUS, 1994a. Work Plan Addendum for Focused Remedial Investigation for Groundwater, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania.

HNUS, 1994b. Remedial Investigation Report for Operable Unit 3, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. August.

HNUS, 1994c. Focused Feasibility Study Report for Operable Unit 3, NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. August.

HNUS, 1994d. Draft Wetlands Assessment for NAWC Warminster, Bucks and Montgomery Counties, Pennsylvania. Aiken, South Carolina.

HNUS, 1995a. Phase III Remedial Investigation Work Plan for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. January.

HNUS, 1995b. Draft Area B Hydrogeologic Report for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. August.

HNUS, 1995d. Site 4 Engineering Evaluation and Cost Analysis (EE/CA) Report for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. July.

HNUS, 1995e. Focused Remedial Investigation for Groundwater Report for NAWC Warminster, Pennsylvania. Wayne, Pennsylvania. July.

ITS, 1993. Analytical Summary of the Post-Excavation Samples from the Removal of Tank No. 18, NAWC Warminster, Pennsylvania. Parsippany, New Jersey. June 23.

JRB Associates, 1981. Hydrogeologic Investigation of the Naval Air Development Center Waste Disposal Sites, Warminster, Pennsylvania; Task 1 – Records Search, Preliminary Site Investigation, and Recommendations for Task 2. McLean, Virginia.

JRB Associates, 1983. Hydrogeologic Investigation of the Naval Air Development Center Waste Disposal Sites, Warminster, Pennsylvania; Task 2 – Final Report: Monitoring Well Installation, Sampling, Analysis of Samples and Groundwater Hydrogeology. McLean, Virginia.

Langard, S., and T. Norseth, 1986, "Chromium." In Handbook on the Toxicology of Metals. Nordberg, and V. B. Vouk, eds., VolII, Elsevier Science Publishers B.V., New York, pp. 185-210.

Long, E. R., and L. G. Morgan. 1989. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, Washington.

Long, E. R., D. D. MacDonald, S. L. Smith, and F. D. Calder, 1995. "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." In Environmental Management. 19:81-97.

Lyman, W.J., W.F. Reehl, and D.H. Rosenblatt, 1990. Handbook of Chemical Property Estimation Methods. American Chemical Society, Washington, DC.

NUS Corporation, 1985. Preliminary Assessment for NADC Warminster, Pennsylvania. Wayne, Pennsylvania.

Ontario Ministry of Environment (MOE), 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Toronto, Ontario.

Probe Environmental, 1992. Soil Analysis Reports and Soil Boring Locations for Lagoon No. 2, NAWC Warminster, Pennsylvania. Mount Laurel, New Jersey. November 23.

Rima, D., H. Meister, and S. Longwill, 1962. Geology and Hydrology of the Stockton Formation in Southeastern Pennsylvania. Bulletin W-14. Pennsylvania Department of Internal Affairs, Topographic and Geologic Survey.

Satterthwaite Associates, Inc., 1984. Final Report on the Groundwater Monitoring and Hydrogeologic Investigation for the Naval Air Development Center, Warminster, Pennsylvanai. West Chester, Pennsylvania.

Sloto, R. and D. Davis, U.S. Geological Survey, 1983. Effect of Urbanization on the Water Resources of Warminster Township, Bucks County, Pennsylvania. Water Resources Investigations 82-4020. Harrisburg, Pennsylvania.

SMC Martin, 1991. Stages I and II – Rough Draft Remedial Investigation Report for NADC Warminster, Pennsylvania. Valley Forge, Pennsylvania. April.

Suter, G. W., 1993. Ecological Risk Assessment. Lewis Publishers. Ann Arbor, Michigan.

Tetra Tech NUS (TtNUS), 1998. Remedial Investigation Report for Area D Sources at NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. September.

TtNUS, 1998b. Verification Sample Analysis Results for Removal Activities at Area A Site 1, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. September 10.

TtNUS, 1998c. Verification Sample Analysis Reuslts for Removal Activities at Area A Site 1A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. October 7.

TtNUS, 1998d. Verification Sampling Results Area A Site 1A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. October 27.

TtNUS, 1998e. Characterization Sampling Results Area A Site 1B, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. November 12.

TtNUS, 1998f. Verification Sample Results, Site 1B, Area A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. November 25.

TtNUS, 1998g. Preliminary Results from Verification and Supplemental Sampling Area A Site 2, NAWC Warminster, Pennsylvania. October 29.

TtNUS, 1998h. Evaluation of Site 2 Soil Data, Area A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. November 12.

TtNUS, 1998i. Verification Sample Results, Site 2A, Area A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. November 25.

TtNUS, 1998j. Verification Sample Results, Excavation 2B, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. December 28.

TtNUS, 1998k. Verification Sample Analysis Results for Removal Activities Area A Site 3, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. October 30.

TtNUS, 1998l. Verification Sampling Results Area A Site 2C, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. October 27.

TtNUS, 1998m. Verification Sampling and Analysis Results for Area A Removal Actions, Site 3, NAWC Warminster, Pennsylvania. King of Prussia. November 13.

TtNUS, 1998n. Results from Additional Geophysical Surveys for Sites 1 and 2 Area A RI/FS, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. December 31.

TtNUS, 1999a. Post Removal Summary Report Area A, Sites 1, 2, and 3, NAWC Warminster, Pennsylvania. King of Prussia. May.

TtNUS, 1999b. Remedial Investigation (RI) Report, Operable Unit 5 (Site 8 Media other than Groundwater) for NAWC Warminster, Pennsylvania, King of Prussia, Pennsylvania. August.

TtNUS, 1999c. Scope of Work for Additional Area C Soil Investigations at NAWC Warminster. King of Prussia, Pennsylvania. October 18.

TtNUS, 1999d. Environmental Investigation Report for the Maintenance Area, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. December .

TtNUS, 1999e. Letter from N. Teamerson, TtNUS, to L. Monaco, Northern Division, Naval Facilities Engineering Command, regarding Results from Area A Supplemental Subsurface Soil Investigations for Site 2, Site 3, and Tank No. 18, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. November 8.

TtNUS, 1999f. Stream Monitoring First Quarter Report for Unnamed Tributary to Little Neshaminy Creek, Area A Sites, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. September.

TtNUS, 1999g. Remedial Investigation Report for Operable Unit 7 (OU-7) Soils and Waste at Sites 6 and 7, Former NAWC, Warminster, Pennsylvania. King of Prussia, Pennsylvania. November.

TtNUS, 1999h. Feasibility Study Report for Operable Unit 7 (OU-7) Soils/Waste at Sites 6/7, Former NAWC, Warminster, Pennsylvania. King of Prussia, Pennsylvania. December.

TtNUS, 2000a. Environmental Investigation Report for the Quarters A, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvania. January.

TtNUS, 2000b. Stream Monitoring Second Quarter Report for Unnamed Tributary to Little Neshaminy Creek, Area A Sites, NAWC Warminster, Pennsylvania. King of Prussia, Pennsylvani. February.

The Nature Conservancy (TNC), 1992. An Inventory of Species of Concern and Significant Natural Communities of the Naval Air Warfare Center, Aircraft Division, Warminster, Pennsylvania. Natural Resources Branch, Northern Division Naval Facilities Engineering Command.

U. S. Department of Agriculture (USDA), 1975. Soil Survey of Bucks and Philadelphia Counties, Pennsylvania. Soil Conservation Service. Washington, DC.

U. S. Navy, 1980. Navy Shore Activity Disposal Fact Form for NADC Warminster. Warminster, Pennsylvania. December.

U. S. Navy, 1981. Notification of Hazardous Waste Sites (Clay-Law Report) for NADC Warminster. Warminster, Pennsylvania. June.

U. S. Navy, 1987. Letter from G. F. Wright, NAWC Warminster to L. Lunsk, Pennsylvania Department of Environmental Protection, regarding Closure of Lagoon No. 1. Warminster, Pennsylvania. October 29.

U. S. Navy, 1990. Emergency Response Plan for NADC Warminster. Warminster, Pennsylvania. August 13.

U. S. Navy, 1994. Letter from S. Bianchi, NAWC Warminster, to L. Lunsk, Pennsylvania Department of Environmental Protection, regarding Closure of Impoundments, Warminster, Pennsylvani. April 1994.

U. S. Navy, 1995. Letter from O. Monaco, Northern Division, Naval Facilities Engineering Command, to D. Kennedy, Pennsylvania Department of Environmental Protection, regarding July 1995 Soil Sampling Results from Treatment Plant Subsurface Soils. Lester, Pennsylvania. August 14.

U. S. Navy, 1999a. Action Memorandum for Removal Action at Site 8 for NAWC Warminster. Warminster, Pennsylvania. February 4.

U. S. Navy, 1999b. Record of Decision for Operable Unit 5 (OU-5) at NAWC Warminster, Pennsylvania. September.

Versar, Inc., 1979 (for EPA). Water-Related Fate of 129 Priority Pollutants. EPA 440/4-79/029. Monitoring and Data Support Division. Washington, DC.

Verschueren, K., 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold. New York, New York.

Wentsel, R. S., R.T. Checkai, T. LaPoint, M. Simini, and L. Brewer, 1994. Procedural Guidelines for Ecological Risk Assessments at U.S. Army Sites. ERDEC-TR-221. Aberdeen Proving Grounds, Maryland.