Final

Work Plan for Baseline Ecological Risk Assessment Site 47

Naval District Washington, Indian Head Indian Head, Maryland

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Acronyms and Abbreviations

µg/kg	micrograms per kilogram
AET	apparent effects threshold
bgs	below ground surface
BERA	Baseline Ecological Risk Assessment
CLEAN	Comprehensive Long-term Environmental Action Navy
COC	chemical of concern
CTO	Contract Task Order
DOC	dissolved organic carbon
DQO	data quality objective
EC50	effects concentration 50 percent
HQ	hazard quotient
IDW	investigation-derived waste
LC_{50}	Lethal concentration 50 percent
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NDWIH	Naval District Washington, Indian Head
NOAEL	no observed adverse effect level
ORP	oxidation/reduction potential
PAH	polycyclic aromatic hydrocarbons
PRG	preliminary remedial goal
QC	quality control
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
RPM	Remedial Project Manager
SERA	screening ecological risk assessment
SVOC	semivolatile organic compound
TAL	target analyte list
TCE	trichloroethene
TCL	target compound list
TOC	total organic carbon
VOC	volatile organic compound

SECTION 1

Introduction

This Baseline Ecological Risk Assessment (BERA) Work Plan for Site 47, the Mercuric Nitrate Disposal Area, located at the Naval District Washington, Indian Head* (NDWIH), Indian Head, Maryland, was prepared in response to Contract Task Order (CTO) 066, under the Comprehensive Long-term Environmental Action Navy (CLEAN), contract number N62470-95-D-6007. It addresses all work activities required to conduct the BERA.

1.1 Document Organization

This BERA Work Plan is organized as follows: Section 1 presents the objectives, document organization, and project organization; Section 2 presents a general description of the facility and the site, a summary of the site history, and a description of previous ecological risk assessment work at the site; Section 3 presents Step 3B of the ecological risk assessment process (the refined problem formulation); Section 4 presents the Study Design and Data Quality Objectives for the BERA; and Section 5 presents a description of the field investigation program. Figures and tables are provided at the end of each section.

1.2 Project Organization

CH2M HILL will conduct this BERA with support from the Navy. The Navy Remedial Project Manager (RPM) will be Mr. Joseph Rail.

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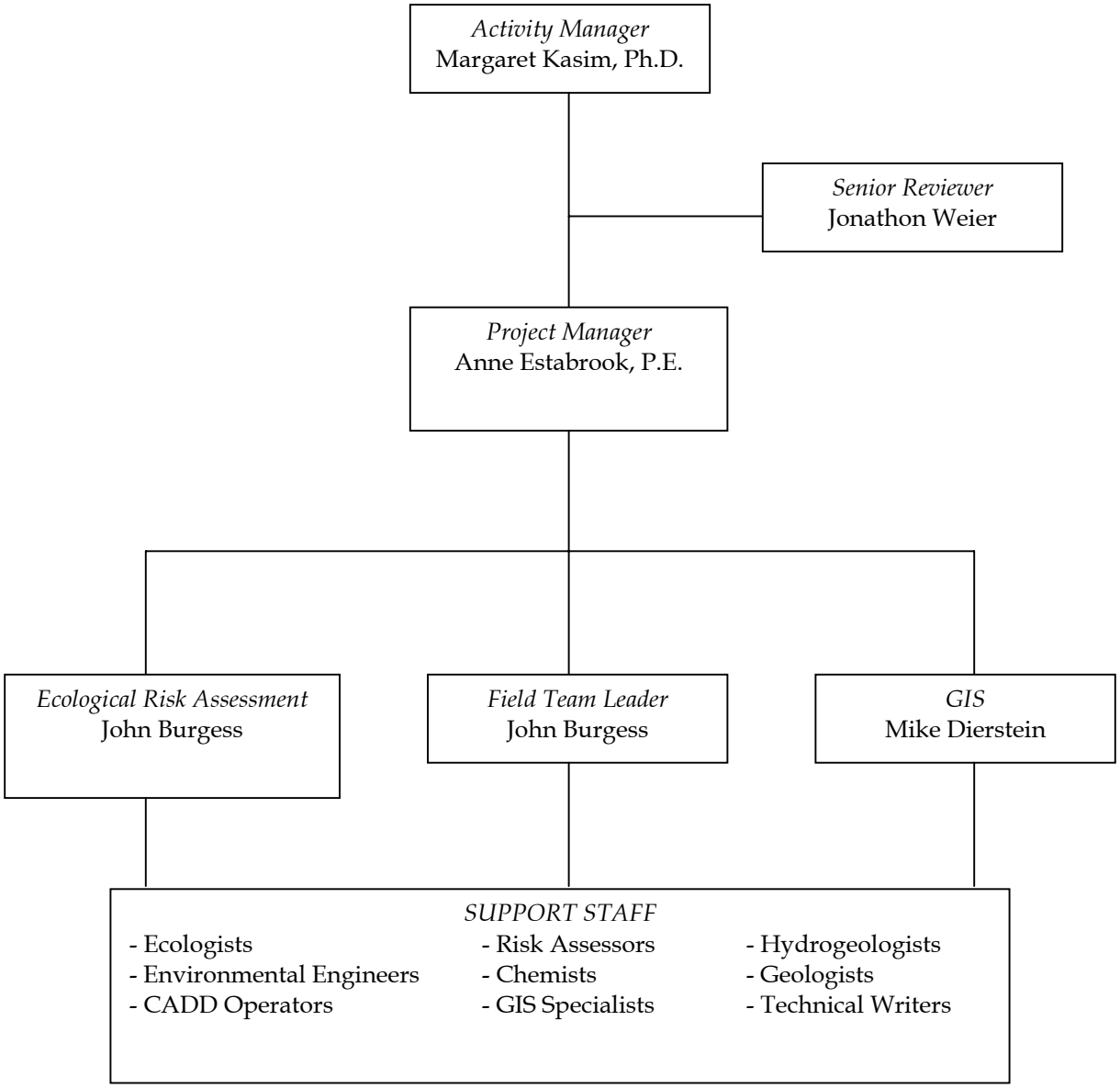
The CH2M HILL project organization is shown in Figure 1-1.

FIGURE 1-1
Project Organization Chart



SECTION 2

Site Background

Naval District Washington, Indian Head is a military facility located in northwestern Charles County, Maryland. The facility is located on Cornwallis Neck Peninsula and is bounded by the Potomac River to the northwest, west and south; Mattawoman Creek to the south and east; and the town of Indian Head to the northeast.

Site 47 (Mercuric Nitrate Disposal Area) is in the northwest-central part of the facility (Figure 2-1). Mercuric nitrate was used in Building 856 as a catalyst in the production of the missile propellant hydrazinium nitroformate and was disposed of at a location near the southeastern corner of the building, near the approximate location of sample SA05 (Figure 2-2). The disposal area consisted of about 24 ft^2 (4 ft by 6 ft) near the drainage ditch that begins near the southeastern corner of the building. The disposal site was covered with limestone chips to provide neutralization for nitric acid, which contained the spent catalyst. An estimated 274 pounds of mercuric nitrate were disposed of at the site between 1957 and 1965 (NEESA, 1988). There is no visual evidence of the disposal area at present. Additionally, the floors and the drainage trenches (that processed the wastewater to Buildings 856A, 856B, and 856C) were lined with leaded flooring. The lead that lined the trenches located outside of Building 856 was removed before the 1999 Remedial Investigation (RI) sampling. Lead in the surface soil at Site 47 may have originated from the leaded floor and lead lined drainage trenches of Building 856 or from the paint on the building.

Drainage in the ditch adjoining the former disposal location flows generally southward. Water in the ditch eventually flows to Mattawoman Creek, about ½ mile south of the site. About 250 ft north of Caffee Road, the ditch becomes a stream. A 300-ft section of stream, immediately downstream of Caffee Road, was excavated in 1994 as part of the remediation for Site 8 (Mercury contamination from Building 766). Mercury was the contaminant of concern in the soil and sediment at Site 8. Mercury was used in laboratory tests in Building 766 from 1953 to 1981 and disposed of through a drainpipe into the stream. Approximately 440 cubic yards of mercury-contaminated soil/sediment were removed from Site 8 and the stream. The removal action was based on a 10-mg/kg-mercury action level. Confirmatory sampling indicated that the removal action was successful (Haliburton NUS, 1995). After the removal action, excavated stream areas were backfilled with 12-in. lifts of common fill and erosion and sediment control measures were installed (OHM, 1995).

Downstream of Site 8 the stream flows through a forested area and then into the Site 12 Pond, an impounded 8-acre water body adjacent to Town Gut Landfill (Site 12). Water released from this impoundment enters Mattawoman Creek via a tidal marsh. Much of the Site 12 Pond has been investigated as part of RI activities for Town Gut Landfill (Site 12) and Sites 8 and 56. Site 56, referred to as Industrial Wastewater Outfall 87, discharged to the stream downstream of Site 8. Site 56 was remediated for lead contaminated sediments in the pipe and at the discharge point. A biomonitoring program was initiated in the Site 12 Pond in 1992 to determine the effect of mercury and lead on biota in the pond. The results of

the biomonitoring did not show any adverse effects on biota in the pond (Brown and Root, 1996).

Historical information obtained subsequent to the initial investigation indicates other potential releases to the environment have occurred, specifically a barium slurry reportedly deposited in a pit on the east side of Building 856, nitroglycerin stored or used at the site and detected in a stormwater manhole, and volatile organic compounds such as carbon tetrachloride and trichloroethene (TCE), which were used or stored at the site and have been detected in groundwater at the site. However, the BERA addresses only potential risk from chemicals in the surface soil, sediment, and surface water at Site 47 because there are no exposure pathways for ecological receptors to come in contact with groundwater at Site 47. Potential human health risks related to groundwater contamination are being addressed separately.

2.1 Environmental Setting

Site 47 is an upland area that gently slopes to the southeast (Figure 2-1). The site is dominated by mowed grass. A narrow drainage ditch originates off the southeastern corner of Building 856 and flows south, towards Caffee Road, eventually becoming a stream. At its beginning, the ditch is about 1 to 2 ft wide with mowed grassy banks. The substrate of the ditch is soil with no wetland vegetation present for most of its length. The drainage ditch broadens to approximately 3 ft in width near Magazine 1070 (Figure 2-2). Near Magazine 1073, some of the bank is unmowed, and standing water and wetland vegetation are present. Herbaceous wetland vegetation in the channel near Magazine 1073 includes beggars-ticks (*Bidens frondosa*), soft rush (*Juncus effusus*), and wool grass (*Scirpus cyperinus*). In addition, tadpoles (unidentified species) have been observed in the drainage ditch upgradient of Magazine 1073. The drainage ditch is bordered by open forest to the east. The forest has a mature canopy with little understory or ground cover. The canopy is dominated by chestnut oak (*Quercus prinus*), sweetgum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*). The subcanopy is dominated by American holly (*Ilex opaca*). The sparse shrub layer is dominated by highbush blueberry (*Vaccinium corymbosum*). The drainage ditch becomes a stream bordered by forest on both sides as it continues south past Building 854 and crosses Caffee Road through a 36-in. culvert. The stream is bordered by upland forest dominated by sweetgum. The stretch of the stream immediately downstream of Caffee Road was excavated as part of the Site 8 remediation. East of the Site 8 excavation area, the stream flows through a forested area before entering the Site 12 Pond.

2.2 Previous Ecological Risk Assessment Activities

A screening ecological risk assessment (SERA) was completed for Site 47 as part of the Final RI for the site (CH2M HILL, 2003). Over the past 3 years, additional investigation work has been conducted to further define the nature and extent of contamination. The results of the SERA suggested that the potential for ecological risk exists at the site.

For all endpoints, there were multiple chemicals that were associated with hazard quotients (HQs) in excess of 1. HQs for mercury were greater than 100 for all endpoints, with the exception of carnivorous terrestrial mammals (represented by red fox). Risks from some

explosive chemicals detected at the site could not be evaluated because screening values were not available. Risk estimates from the SERA were as follows:

Soil Invertebrates and Plants. HQs > 1 were calculated for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and inorganics.

Insectivorous Terrestrial Birds. HQs for aluminum, cadmium, chromium, cobalt, copper, lead, mercury, selenium, vanadium, and zinc exceeded 1.

Herbivorous Birds. HQs for aluminum, chromium, lead, mercury, and zinc exceeded 1.

Carnivorous Birds. HQs for aluminum, lead, and mercury exceeded 1.

Omnivorous Terrestrial Mammals. HQs for aluminum, antimony, arsenic, barium, cadmium, copper, iron, lead, mercury, selenium, silver, thallium, vanadium, and zinc exceeded 1.

Carnivorous Terrestrial Mammals. HQs for aluminum, iron, lead, mercury, and vanadium exceeded 1.

2.2.1 Data Collected to Fill Data Gaps

After the Draft RI for Site 47, which included the SERA, was completed, several data gaps were identified. Additional samples were collected to fill these data gaps, including groundwater, soil, sediment, and surface water samples. The sampling activities relevant to the BERA are described below.

Since some contaminants were detected above screening levels in soil in the main drainage ditch, and the nature and extent of contamination along the ditch had not been fully defined, sediment and surface water sampling was conducted in the stream downgradient of the site. The purpose of the supplemental investigation was to determine if contamination has been transported along the drainage ditch by surface water runoff into the stream. The extent of the investigation involved the area between Caffee Road and the point at which the stream forms, in the vicinity of sampling location IS47SS16 (Figure 2-2). Sampling downstream of Caffee Road was unnecessary in defining the nature and extent of contamination related to Site 47 because this reach of the stream was remediated due to the contamination associated with Site 8.

In addition to the stream investigation, two additional soil samples (IS47SS14 and IS47SS15) were collected from two small drainage ditches at Site 47 to help characterize potential contamination in these ditches from surface runoff events. These samples were included in the evaluation of the surface soil at Site 47.

Although not directly attributed to Site 47, an additional investigation was implemented at a suspected chemical disposal area across Caffee Road from Building 766 because of reports that miscellaneous laboratory wastes were disposed of there (Figure 2-2). Soil samples were collected from the suspected chemical disposal area, which is located in a moist wooded area adjacent to the stream described above. This investigation was conducted to determine the nature and extent of the suspected release. Given the small size and isolated nature of the Chemical Disposal Area, the Navy has decided to conduct a soil removal action for the

area rather than perform additional ecological risk investigations. Therefore, no additional studies are proposed for the Chemical Disposal Area in this work plan.

All samples were submitted for analysis for the full target compound list (TCL) and target analyte list (TAL), and total organic carbon (TOC). Explosives were not analyzed for in stream samples because no explosives were detected in the ditch upgradient of the stream.

2.2.2 Results of Step 3A of the BERA

Since the SERA concluded that further evaluation was warranted, the initial step of a BERA, Step 3, was conducted and presented in a draft technical memorandum (CH2M HILL, 2002a). Step 3 comprises two phases, Step 3A and Step 3B. In Step 3A, risk estimates are recalculated based on refined exposure assumptions, site-specific data, spatial distribution, and/or detailed literature review. Step 3B is the problem formulation phase of the BERA. It involves an evaluation of the toxicity of site-related chemicals, and the refinement of the assessment endpoints and conceptual model developed in the SERA. The BERA problem formulation (Step 3B) is presented in Section 3 of this work plan.

2.2.2.1 Site 47 Surface Soil

Several metals and polycyclic aromatic hydrocarbons (PAHs) were identified as posing potential risk to soil invertebrates or plants. Based on a review of the spatial distribution of these chemicals of concern (COCs), the distribution of metals with concentrations above screening values appears to be widespread over the entire site, with the exception of cyanide, lead, and zinc. Cyanide was detected above the screening value at 8 of 27 sampling locations. All of the cyanide exceedences were south of Building 856 and in the drainage ditch. Lead was detected above the screening value at 10 of the 29 sampling locations and zinc was detected above the screening value at 9 of 29 sampling locations. In contrast, the remaining inorganic COCs were detected above the screening value in 20 or more of the 29 sampling locations. Exceedences for lead were scattered, while exceedences for zinc occurred primarily at sampling locations in the vicinity of Building 856.

Although several metals were measured above soil screening values across the entire site, the table below compares the concentrations of the metals for which NDWIH background concentrations (Tetra Tech NUS, 2002) were available. No background data were available for cyanide.

Chemical	Average Site Concentration (mg/kg)	Average Background Concentration (mg/kg)	Site/Background Ratio
Aluminum	4,212	7,540	0.6
Chromium	11.2	13.6	0.8
Iron	8,435	13,000	0.6
Lead	134	18.7	**7.2**
Mercury	3.18	0.06	**53.0**
Silver	68.0	0.6	**113.3**
Vanadium	13.6	23.3	0.6
Zinc	83.7	20.2	**4.1**

As shown in the table, the concentrations of aluminum, chromium, iron, and vanadium are below background levels. While it cannot be concluded that these metals pose no risk to plants or soil invertebrates at Site 47, the results of this comparison provide evidence to suggest that site-related risk may be overestimated. Although a potential risk is indicated by exceedance of the screening value, the risk may be naturally occurring or the metal may not pose a significant risk due to limited bioavailability in the local soil. However, the comparison does show that lead, mercury, silver, and zinc are present at concentrations substantially higher than local background concentrations.

2.2.2.2 Sediment and Surface Water in the Stream

As described previously, the scope of the remedial investigation at Site 47 was expanded after the SERA was completed to include the stream downgradient of the main drainage ditch, which conveys surface runoff from the site toward Caffee Road. The ditch becomes a stream before it reaches Caffee Road. This portion of the risk assessment was focused on evaluating potential contamination and risk in the stream where it functions as aquatic habitat. Therefore, samples IS47SS16 and IS47SS17, although labeled as soil samples, were treated as sediment samples in Step 3A of the ERA because true aquatic habitat is present at these locations These two samples were included in the sediment evaluation along with the two sediment samples collected closest to Caffee Road (IS47SD05 and IS47SD06). Additionally, a small ditch just south of the bunkers functions as true aquatic habitat and contributes flow to the stream. Therefore the sample (IS47SS18) collected from this ditch was also included as a sediment sample in Step 3A. The stream is very shallow, bordering on intermittent in nature, and as such provides no viable habitat for fish or aquatic birds, but does provide habitat for amphibians and aquatic invertebrates. The only upper trophic level receptor group evaluated for this area was semiaquatic mammals, represented by raccoon. For conservative purposes, an area use factor of one was used to evaluate a worst-case exposure for this receptor. No risks were identified for semi-aquatic mammals.

Two metals (mercury and silver) and two SVOCs (diethylphthalate and phenanthrene) were identified as COCs for the sediments at Site 47. The area where concentrations of these chemicals were above the screening values was limited to the upper part of the main drainage ditch (i.e., samples IS47SS16, IS47SS17, and IS47SD05). The sample collected from the small drainage ditch below the bunkers (IS47SS18) and the furthest downgradient sample (IS47SD06) did not contain mercury, silver, or diethylphthalate and the concentration of phenanthrene was below the screening value. Therefore the potential risk to the benthic invertebrate community from these chemicals is limited to the upper part of the drainage ditch (i.e., north of sample IS47SD05), a stretch of about 250 ft.

Although diethlyphthalate was identified as posing a potential risk, it is likely that the risk is overestimated for this chemical. Diethlyphthalate was detected in only one of the sediment samples (IS47SS16) at a concentration of 520 μg/kg. The USEPA Region III screening value for this chemical is 200 μg/kg and is based on an apparent effects threshold (AET), which is derived by identifying the sample with the highest diethylphthalate concentration and no adverse biological effect from a whole sediment toxicity data set. Effects could be apparent in samples with higher diethlyphthalate concentrations, but due to other compounds. Thus, the AET has a high degree of uncertainty. Other diethlyphthalate screening values are available in the literature, including 630 μg/kg (USEPA, 1996) and 600

µg/kg (Jones et al., 1997). There is evidence to suggest that the screening value comparison overestimates the potential risk. The evidence includes the following: this chemical was detected in only one of the sediment samples, there is uncertainty in the screening value used in the SERA, and the detected concentration is below two other published screening values. The one detect in the drainage ditch is bounded by nondetects in the upgradient and downgradient samples. In addition, diethylphthalate was detected in only 2 of the 29 surface soil samples around building 856 (upgradient of the ditch), and the detection is possibly a laboratory artifact, as diethylphthalate is a common laboratory contaminant (USEPA, 1992). Therefore, it is unlikely that this chemical poses a significant risk to the benthic community in the intermittent stream. Therefore this chemical will not be evaluated further as a COC in the BERA.

Four metals, aluminum, iron, manganese, and zinc, were identified as COCs for surface water in the stream. The surface water samples were collected at locations IS47SW01 and IS47SW02, shown on Figure 2-2. The surface water data were total, unfiltered concentrations. The dissolved fractions of these metals would likely be lower. These exceedances might be representative of the local geological conditions, but the potential risk to the water column community cannot be dismissed at this point in the evaluation, since local background surface water concentrations have not been established.

2.2.2.3 Surface Soil at the Suspected Chemical Disposal Area

As described previously, the scope of the remedial investigation at Site 47 was expanded after the SERA was completed to include the suspected chemical disposal area in the wooded area west of Building 766.

Four metals and several PAHs were identified as COCs for the Suspected Chemical Disposal Area. Aluminum, chromium, iron, and vanadium were detected and exceeded their screening values at each location. As shown in the table, these metals are at or below background concentrations. Therefore, while it cannot be concluded that these metals pose no risk to plants or soil invertebrates, the potential risk as indicated by exceedance of the screening value, may be naturally occurring or the metal may not pose a significant risk due to limited bioavailability in the local soil.

Chemical	Average Site Concentration (mg/kg)	Average Background Concentration (mg/kg)	Site/Background Ratio
Aluminum	2,955	7,540	0.4
Chromium	6.83	13.6	0.5
Iron	8,288	13,000	0.6
Vanadium	20.1	23.3	0.9

PAHs were found mostly at location IS47SS19, the location closest to Building 766. Five of the nine PAHs detected were detected only at this location. One chemical in particular, phenanthrene, was detected above the screening value at three of the four locations. However, the concentrations at locations other than IS47SS19 were only slightly greater than the screening value. Overall, the organic contamination in this wooded area seems to be

limited to the vicinity of sampling location IS47SS19. There were few organic chemicals detected at the other three locations and those that were, were present at much lower concentrations.

As mentioned in Section 2.2.2.2, the Navy has decided to conduct a soil removal action for the area rather than perform additional ecological risk investigations. A preliminary remedial goal (PRG) for this area may be the 1,000 µg/kg total PAH value published by Beyer (1990) and MHSPE (1994).

2.2.2.4 Food Web Exposures

Based on food web modeling, three metals (lead, mercury, and zinc) were identified as posing a potential risk to upper trophic level receptors. Although the calculated exposures for these metals did not exceed the lowest observed adverse effect level (LOAEL) values for any of the receptor groups, they did exceed the no observed adverse effect level (NOAEL) for three of the receptor groups. Lead was identified as a foodweb COC for insectivorous and herbivorous birds, while mercury was identified as a COC for omnivorous mammals and insectivorous birds, and zinc was identified as a COC for insectivorous birds. Therefore a potential risk to upper trophic level receptors from lead, mercury, and zinc in surface soils at Site 47 cannot be dismissed based on the available data.

2.3 BERA Areas of Concern

The driver COCs identified for Site 47 after Step 3A are shown in the table below. Although, aluminum, chromium, iron, and vanadium were identified as COCs, the background evaluation showed that they are present at background concentrations. Therefore, the BERA will be focused on evaluation of the potential risk posed by the other COCs, which are present above background levels and are likely site-related.

Based on visual inspection, vegetation (aquatic and terrestrial) is growing and shows no obvious signs of stress. Although the absence of gross chemically induced adverse effects on the physical structure of these environments does not preclude the potential for other, less apparent effects, it demonstrates that the substrate will support a vegetative community. As such, plants were excluded from further consideration in the BERA.

Driver COCs are as follows:

Site 47 Surface Soil		Sediment and Surface Water in the Stream	
Soil Invertebrates	**Upper Trophic Level Receptors**	**Benthic Invertebrates**	**Water Column Receptors (Invertebrates and Amphibians)**
Lead	Lead	Mercury	Aluminum
Mercury	Mercury	Silver	Iron
Silver	Zinc	Phenanthrene	Manganese
Zinc	—	—	Zinc
Acenaphthylene	—	—	—

Site 47 Surface Soil		Sediment and Surface Water in the Stream	
Soil Invertebrates	**Upper Trophic Level Receptors**	**Benthic Invertebrates**	**Water Column Receptors (Invertebrates and Amphibians)**
Anthracene	—	—	—
Benzo(a)anthracene	—	—	—
Benzo(a)pyrene	—	—	—
Benzo(b)fluoranthene	—	—	—
Benzo(g,h,i)perylene	—	—	—
Benzo(k)fluoranthene	—	—	—
Chrysene	—	—	—
Dibenz(a,h)anthracene	—	—	—
Fluoranthene	—	—	—
Indeno(1,2,3-cd)pyrene	—	—	—
Naphthalene	—	—	—
Phenanthrene	—	—	—
Pyrene	—	—	—

2.3.1 Spatial Distribution of COCs in Surface Soil Near Building 856

As shown in the table above, four metals (lead, mercury, silver, and zinc) and several PAHs were identified as soil-associated COCs at Site 47 that require further evaluation. Table 2-1 presents the sample-specific concentration of each COC compared to its corresponding screening value. For purposes of this evaluation, the sum of detected PAH compounds was calculated to determine a total PAH concentration for each sample location. One-half the reporting limit was used to represent concentrations of PAHs that were undetected in specific samples. Since total PAHs concentrations were not calculated in the SERA, a screening value of 4,100 μg/kg (MSPHE, 1994) was used for this spatial evaluation.

Included in Table 2-1 is a summary of the number of COCs that exceeded their corresponding screening values at each sample location, as well as a summary of the hazard quotients (HQs) exceeding one.

Figures 2-3 (lead), 2-4 (mercury), 2-5 (silver), 2-6 (zinc) and 2-7 (total PAHs) depict the spatial distribution of where these COCs exceed the screening values in the Building 856 area.

2.3.1.1 Lead

The detected concentration of lead exceeded the soil screening value at 10 of 30 surface soil sample locations. The range of the HQs was 1.0 (SA01) to 26.2 (SS06) (Figure 2-3). Most of the concentrations that exceeded the screening value (seven of the 10 samples) were in samples collected south of, or adjacent to Building 856 (Figure 2-3). The highest HQ (26.2)

occurred at SS06, which is adjacent to Building 856C and within 25 ft south of Building 856. There were no concentrations in excess of the lead screening value in the cluster of samples in the eastern portion of the site between Building 856 and the main drainage ditch.

2.3.1.2 Mercury

Elevated mercury concentrations are widespread at Site 47. The detected concentration of mercury exceeded the soil screening value at 27 of 30 sample locations. The range of HQs was 1.0 (SA10) to 474 (SS02) (Figure 2-4). Most of the highest mercury concentrations were found in samples south of Building 856 (Figure 2-4). However, there were also exceedances north of Building 856, notably SS02 (HQ of 474). Of the soil samples collected south of Building 856, four samples located directly east of Building 1794 (SD01, SD02, SS14, and SA01) had mercury concentrations greater than 10 times the screening value. Four other samples collected closer to Building 856 (SS06, SS07, SA06, and SA08) also contained mercury concentrations more than 10 times the screening value (Figure 2-4).

2.3.1.3 Silver

Similar to mercury, elevated silver concentrations are widespread at Site 47 and the spatial extent of exceedances nearly matches the pattern exhibited by mercury (Figure 2-5). The detected concentration of silver exceeded the soil screening value at 20 of 30 sample locations. The range of these HQs was 1.5 (SS03) to 407 (SD01) (Figure 2-5). The majority of samples which exhibited the highest silver HQs occurred south of Building 856, with seven samples yielding HQs greater than 10.

2.3.1.4 Zinc

Elevated zinc concentrations were not as widespread as mercury and silver concentrations at Site 47. The detected concentration of zinc exceeded the soil screening value at 9 of 30 sample locations. The range of the HQs was 1.0 (SA05) to 15.2 (SS02) (Figure 2-6). Only one sample (SS02) resulted in an HQ greater than 10 (HQ of 15.2), which was located directly adjacent to the north side of Buildings 856 and the west side of Building 856B. There were no other samples collected north of Building 856 that contained zinc concentrations greater than the screening value.

2.3.1.5 PAHs

The detected concentration of total PAHs exceeded the soil screening value at 9 of 30 sample locations. The range of the HQs was 1.0 (SS01) to 6.2 (SD02) (Figure 2-7). The sample with the highest total PAH concentration (SD02, HQ of 6.2), was located at the beginning of the main drainage ditch that conveys runoff south from the Building 856 area (Figure 2-7). There were six sample locations with HQs between >1 and <2, four of which were within 25 ft of Building 856, SS01 and SS02 to the north of Building 856 and SA05 and SS06 to the south of Building 856 (Figure 2-7). There were no total PAH concentrations in excess of the screening value in the area south of the drainage ditch.

Table 2-1
Summary of Detected COC Concentrations, Hazard Quotients (HQs) and Spatial Frequency of Exceedence (FOE) in Site 47 Surface Soil
NDWIH, Indian Head, Maryland

Sample ID	# COCs Exceeding SVs[1]	Lead (Figure 2-2)		Mercury (Figure 2-3)		Silver (Figure 2-4)		Zinc (Figure 2-5)		PAHs, total[3] (Figure 2-6)	
		Conc. (mg/kg)	HQs > 1	Conc. (mg/kg)	HQs > 1	Conc. (mg/kg)	HQs > 1	Conc. (mg/kg)	HQs > 1	Conc. (ug/kg)	HQs > 1
SA01	5	52.4	1.0	2.10	21.0	28.9	14.5	58.8	1.2	8,086	2.0
SA02	2	22.3		0.34	3.4	11.4	5.7	40.5		3,964	
SA03	1	ND[4]		0.36	3.6	ND		ND		3,111	
SA04	0	9.10		ND		ND		10.7		1,904	
SA05	4	48.5		0.54	5.4	15.5	7.8	51.3	1.0	7,515	1.8
SA06	1	8.90		1.60	16.0	1.90		ND		2,023	
SA07	1	12.3		0.40	4.0	ND		14.8		2,218	
SA08	2	12.3		15.9	159.0	3.40	1.7	8.20		1,681	
SA09	2	13.1		0.11	1.1	13.4	6.7	ND		2,975	
SA10	2	15.2		0.10	1.0	2.90	1.5	ND		1,690	
SA11	1	9.30		0.97	9.7	ND		ND		2,368	
SA12	2	5.10		0.22	2.2	3.90	2.0	ND		2,468	
SS14	4	109	2.2	2.00	20.0	212	106.0	263	5.3	990	
SS15	1	34.3		0.19	1.9	ND		34.5		414	
SD01	5	289	5.8	2.90	29.0	814	407.0	372	7.4	5,305	1.3
SD02	3	74.9	1.5	3.80	38.0	40.5	20.3	ND		25,246	6.2
SD03	2	ND		0.35	3.5	4.90	2.5	ND		2,092	
SD04	2	7.10		0.21	2.1	3.60	1.8	ND		2,511	
SS01	2	35.3		0.51	5.1	3.30	1.7	ND		4,193	1.0
SS02	5	982	19.6	47.4	474.0	40.3	20.2	762	15.2	5,039	1.2
SS03	3	51.4	1.0	0.20	2.0	2.90	1.5	ND		17,695	4.3
SS04	1	7.50		0.14	1.4	0.29		ND		3,178	
SS05	4	561	11.2	0.94	9.4	259	129.5	235	4.7	2,830	
SS06	4	1,310	26.2	5.50	55.0	474	237.0	96.8	1.9	5,602	1.4
SS07	4	94.3	1.9	3.70	37.0	22.3	11.2	102	2.0	2,966	
SS08	1	12.1		ND		4.30	2.2	ND		3,512	
SS09	1	8.90		0.20	2.0	1.20		ND		2,454	
SS10	5	89.2	1.8	0.99	9.9	5.90	3.0	255	5.1	8,845	2.2
SS11	0	13.5		0.080		0.39		ND		2,836	
SS12	1	19.5		0.65	6.5	1.20		ND		2,305	
Screening Value		50		0.1		2		50		4100	
FOE[5]		10	--	27	--	20	--	9	--	9	--

Notes:
Sample IDs are truncated for ease of reference (e.g., IS47SA01 is included as SA01)
Shaded cells indicate sample-specific concentrations exceeding the surface soil screening value
1 - SV = screening value
2 - HQ = hazard quotient
3- Total PAHs calculated by using 1/2 the reporting limit for undetected individual PAH compounds
4 - ND = not detected
5 - FOE = frequeny of exceedence

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr

LEGEND

- Site Boundary
- Perennial Swale
- Intermittent Swale
- 5 Foot Elevation Contours
- 1 Foot Elevation Contours
- Railroads
- Approximate Location of Pits and Disposal Areas
- Buildings
- Asphalt Road
- Dirt Road
- Gravel Road
- Vegetation
- 30 = Elevation (feet above mean sea level)

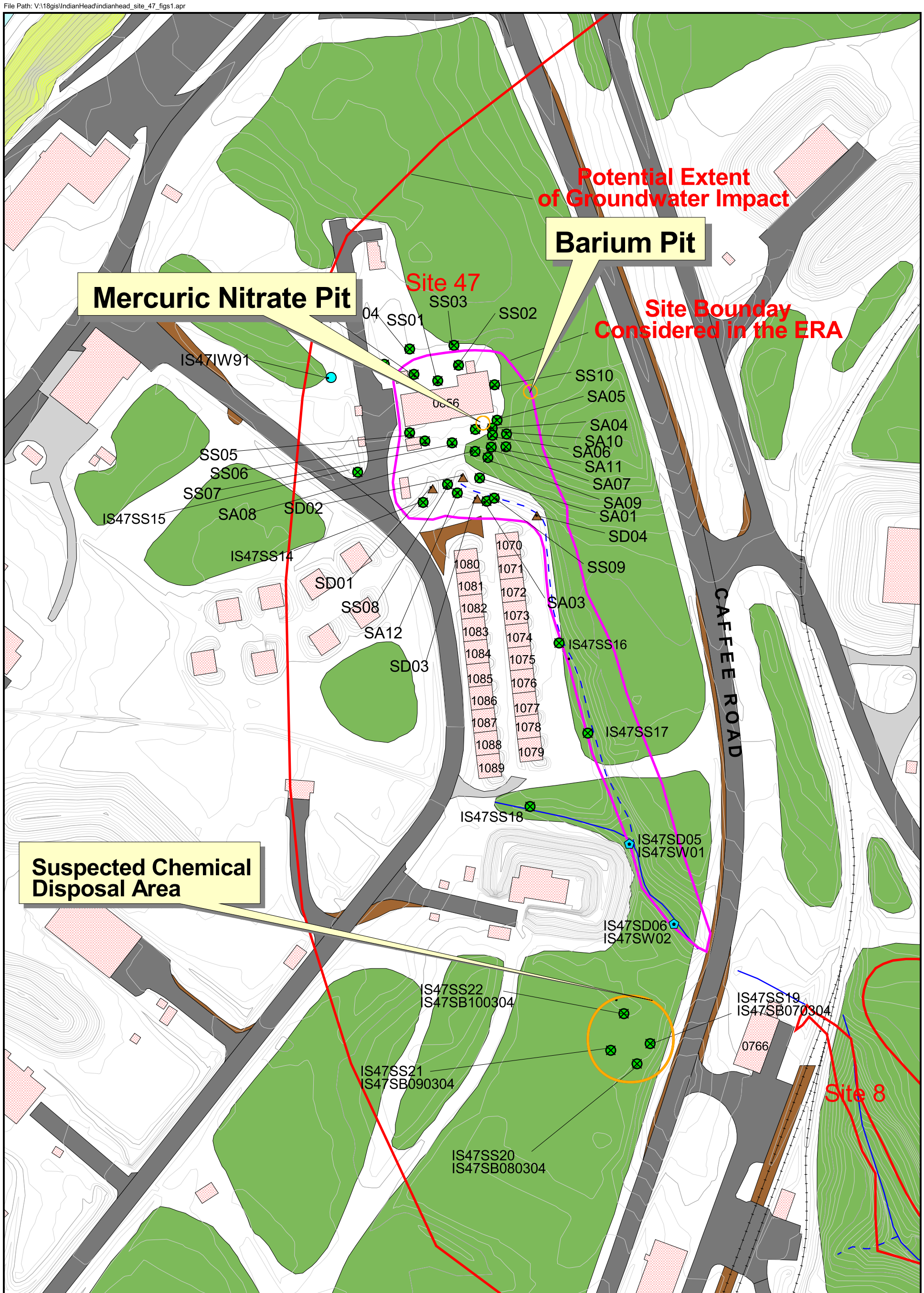
N

100 0 100 200 300 Feet

Figure 2-1
Site Location Map
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

File Path: V:\18gis\IndianHead\indianhead_site_47_figs1.apr



LEGEND

- Surface Soil Sample Location
- Surface Water and Sediment Sample Location
- Sediment Sample Location
- Industrial Wastewater Manhole
- IR Sites
- Water Bodies
- Approximate Location of Pits and Disposal Areas

N

50 0 50 100 Feet

Figure 2-2
Previous Sample Locations
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr

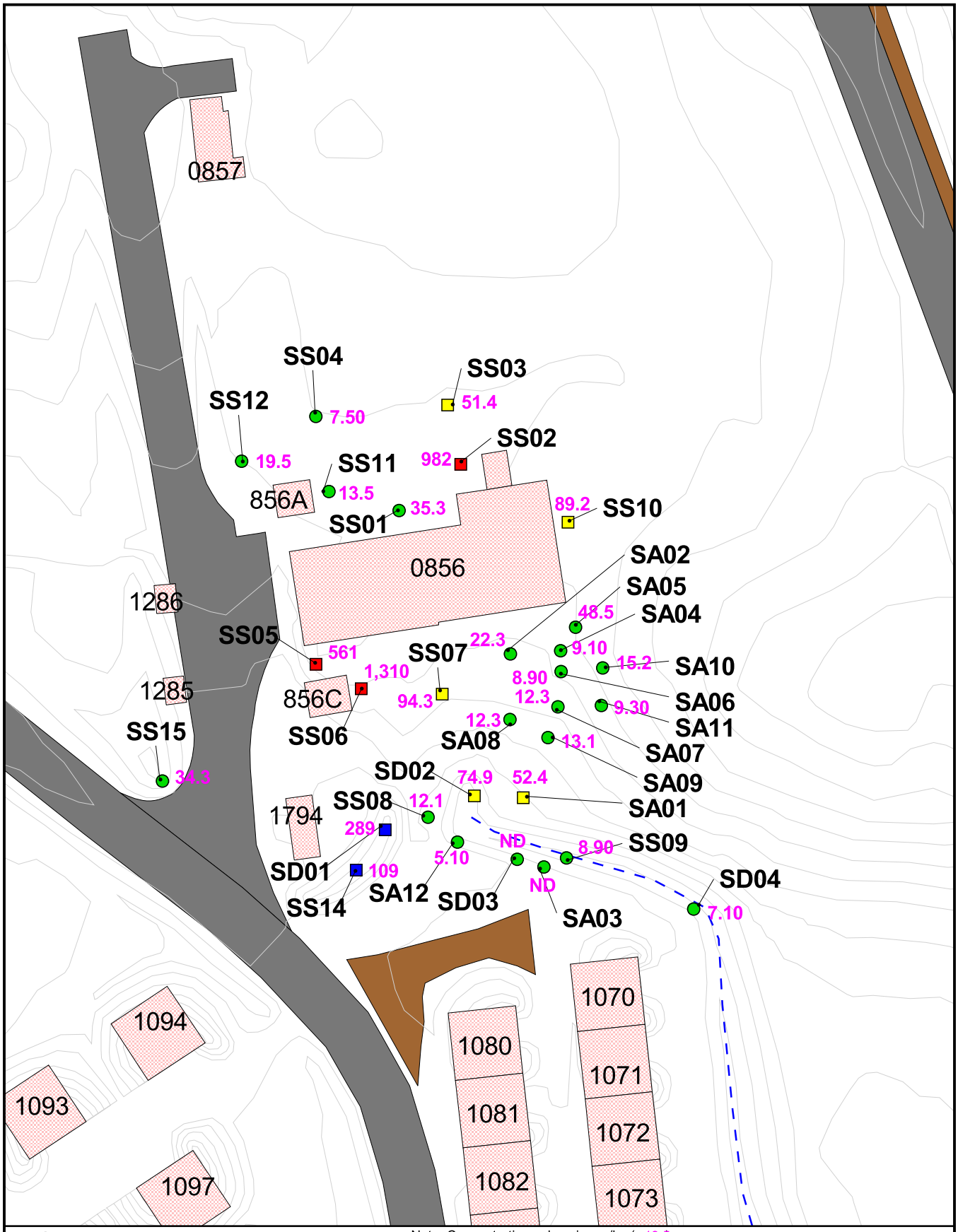
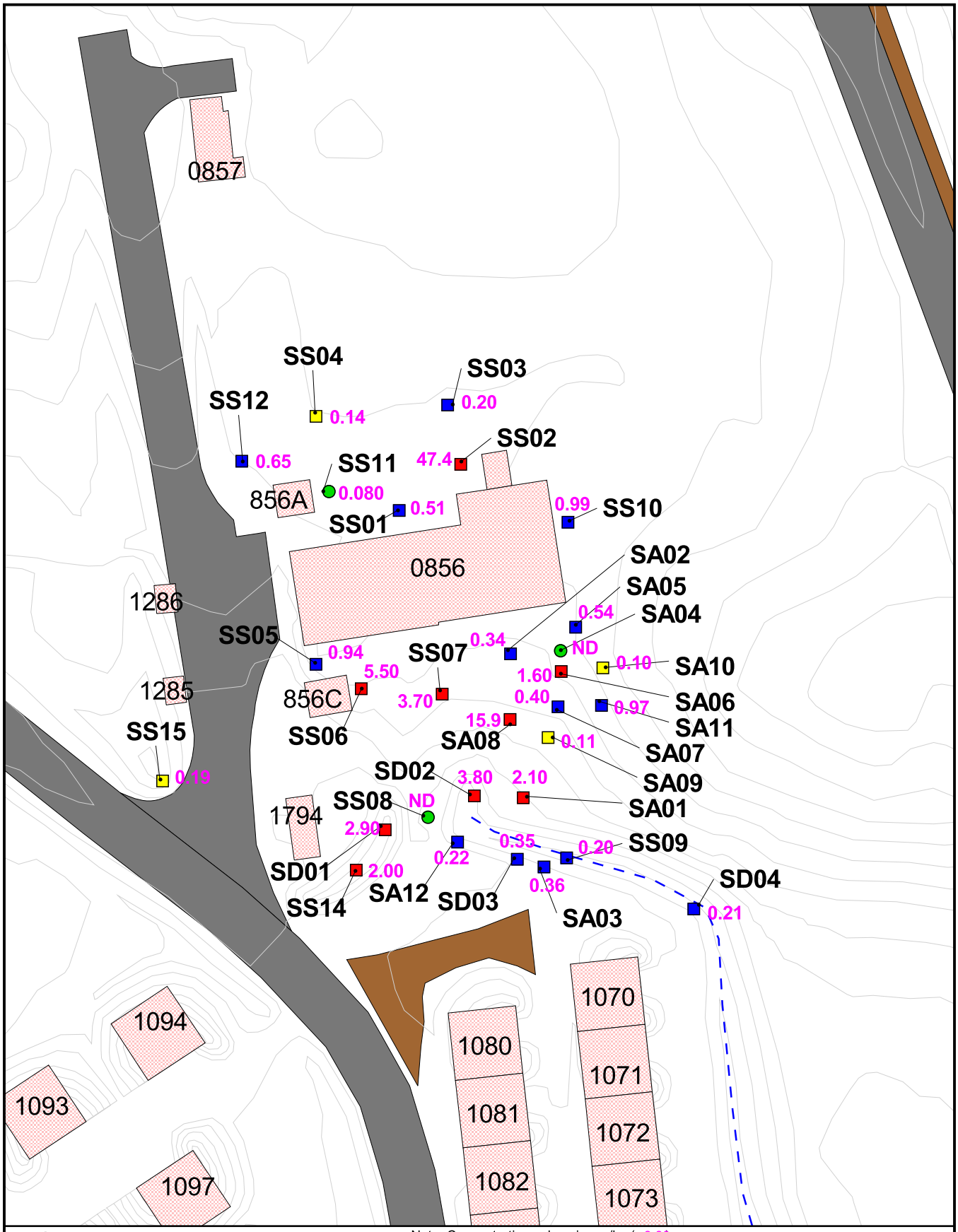


Figure 2-3
Spatial Distribution of Lead
in Surface Soil Samples
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr



LEGEND

- Hazard Quotient (HQ) < 1
- HQ ≥ 1 and < 2
- HQ ≥ 2 and < 10
- HQ > 10
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

Note: Concentration values in mg/kg (3.80).
ND = Not Detected

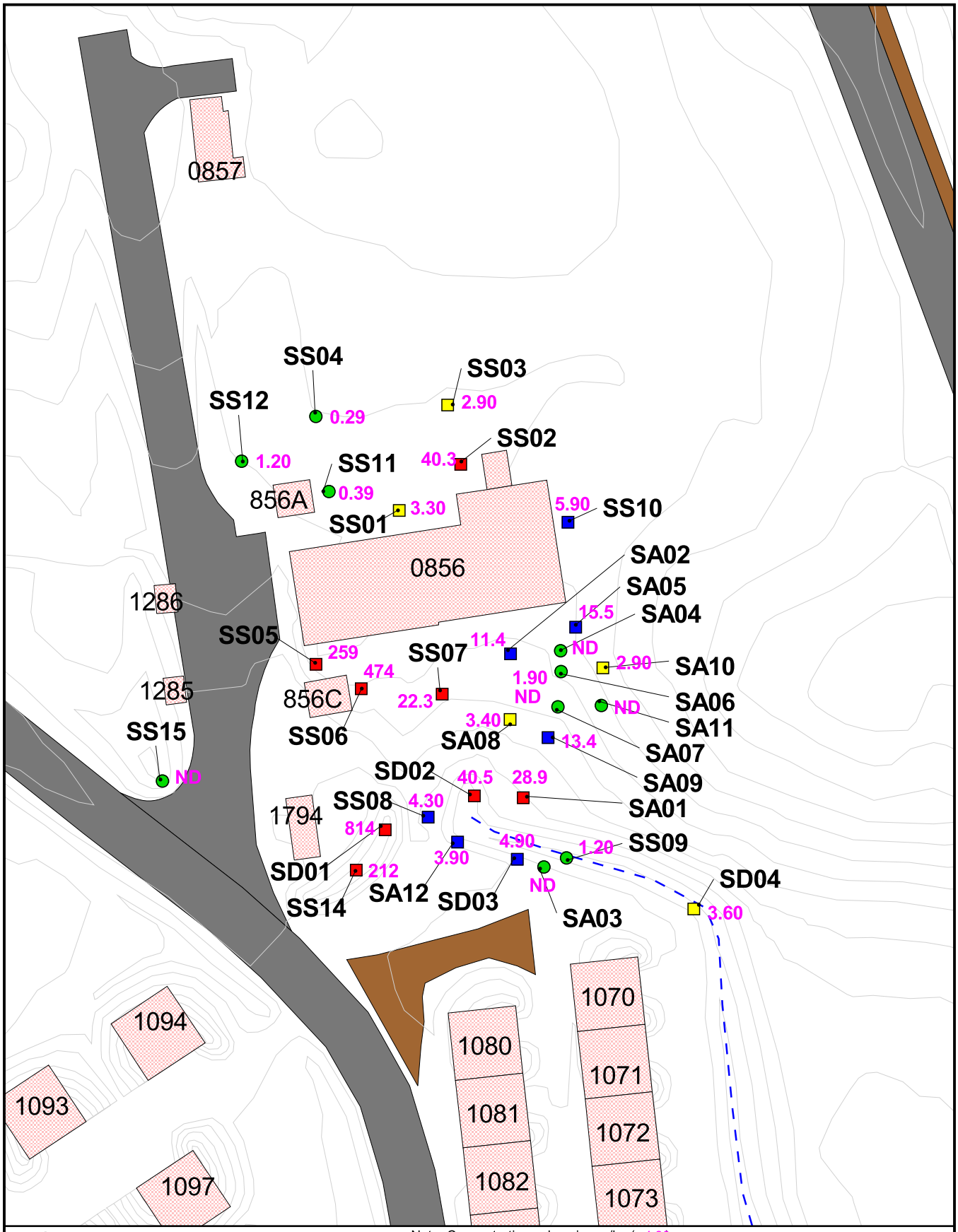
N

0 25 50 Feet

Figure 2-4
Spatial Distribution of Mercury
in Surface Soil Samples
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr



LEGEND

- Hazard Quotient (HQ) < 1
- HQ ≥ 1 and < 2
- HQ ≥ 2 and < 10
- HQ > 10
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

Note: Concentration values in mg/kg (4.30).
ND = Not Detected

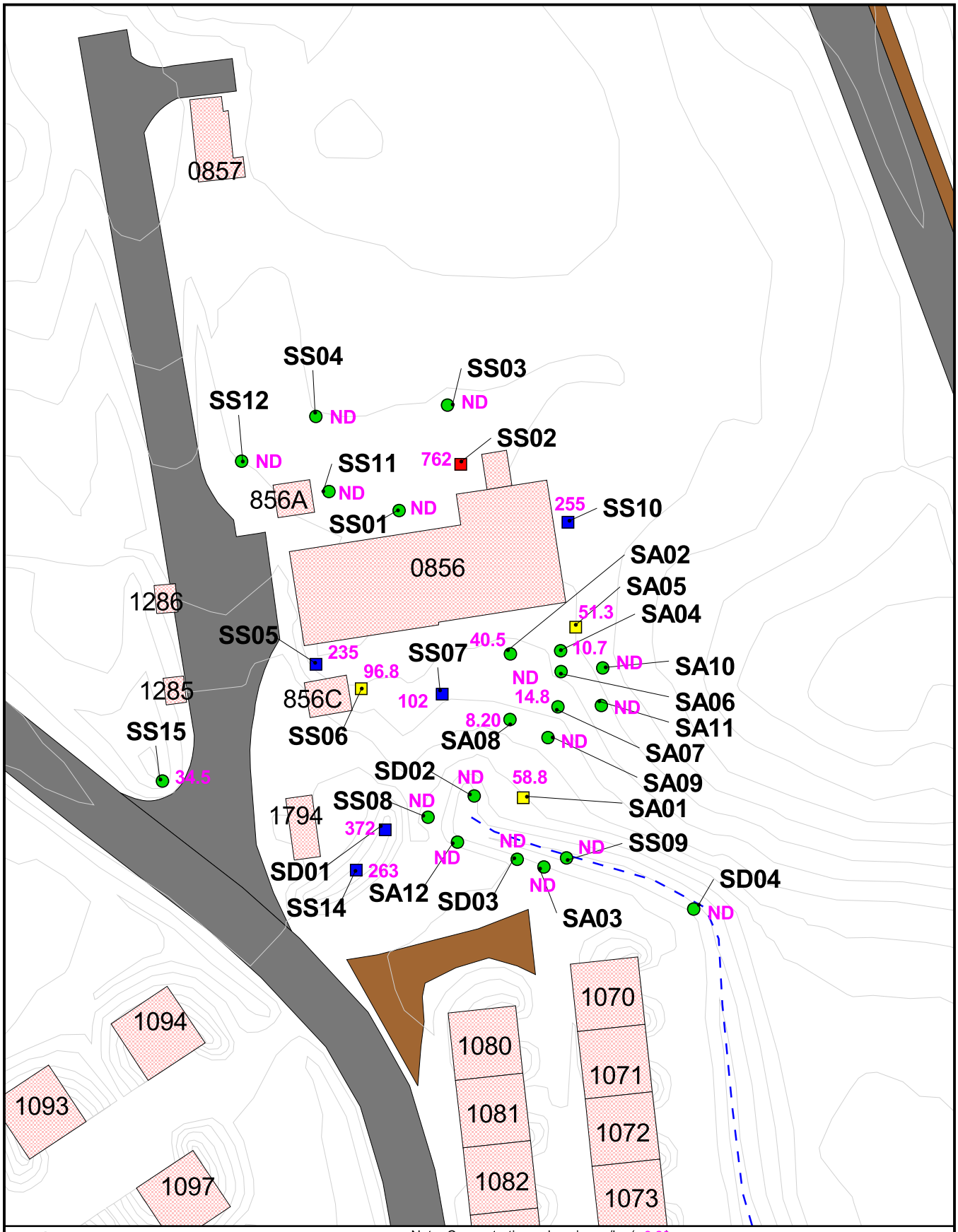
N

0 25 50 Feet

Figure 2-5
Spatial Distribution of Silver
in Surface Soil Samples
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr



LEGEND

- Hazard Quotient (HQ) < 1
- HQ ≥ 1 and < 2
- HQ ≥ 2 and < 10
- HQ > 10
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

Note: Concentration values in mg/kg (8.20).
ND = Not Detected

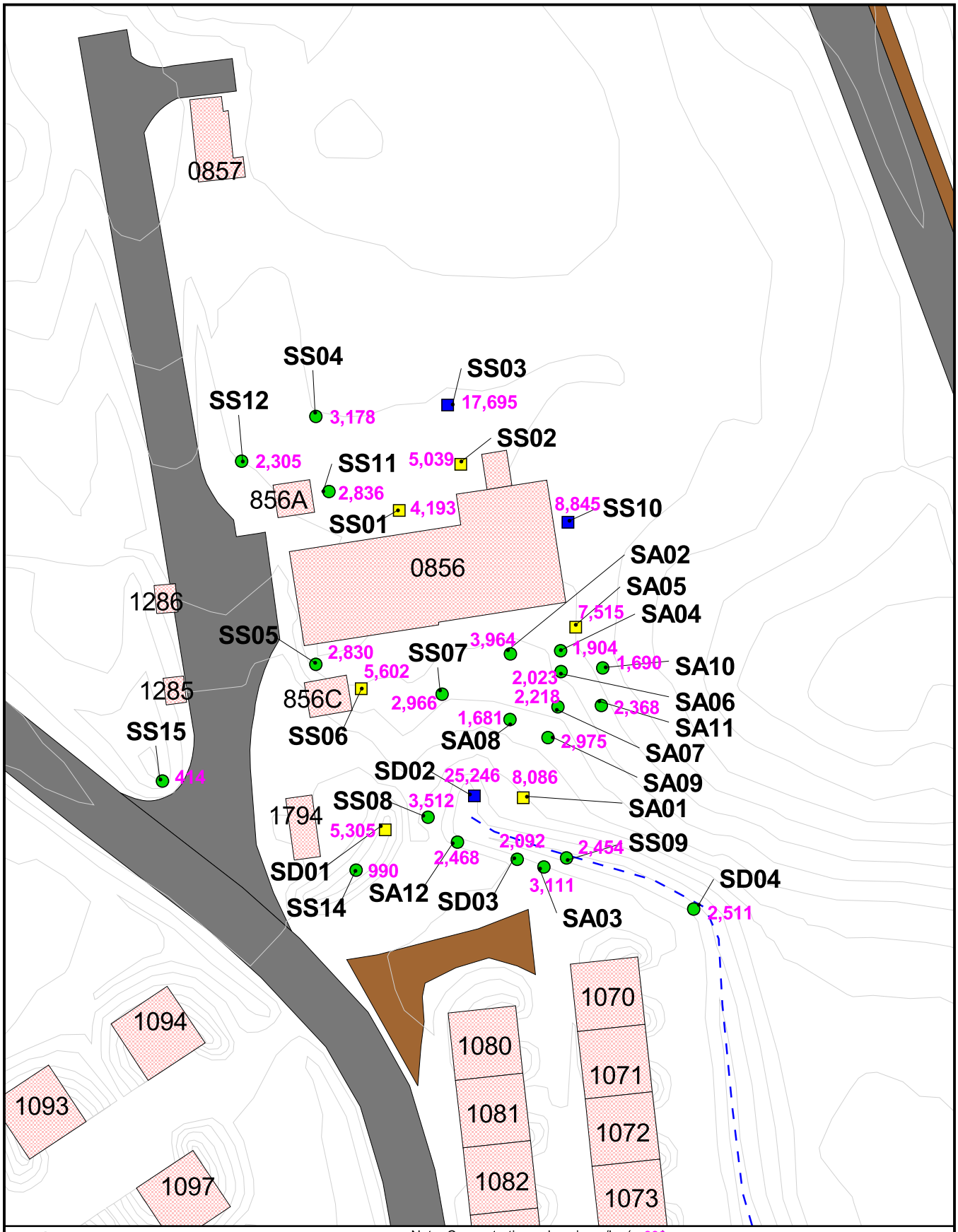
N

0 25 50 Feet

Figure 2-6
Spatial Distribution of Zinc
in Surface Soil Samples
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

File Path: v:\18gis\indianhead\indianhead_site_47_figs1.apr



LEGEND

- Hazard Quotient (HQ) < 1
- HQ ≥ 1 and < 2
- HQ ≥ 2 and < 10
- HQ > 10
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

Note: Concentration values in ug/kg (990).
ND = Not Detected

N

0 25 50 Feet

Figure 2-7
Spatial Distribution of PAHs
in Surface Soil Samples
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

SECTION 3

Baseline ERA Problem Formulation

The baseline ERA problem formulation is a revision of the previous problem formulation from the SERA and is focused on defining the issues associated with the COCs identified from the results of Step 3A. This revised problem formulation consists of an evaluation of the toxicity of the COCs and a refined conceptual model. The conceptual model includes a discussion of exposure pathways, assessment endpoints, and risk hypotheses.

3.1 Ecotoxicity Review

The classes of compounds from which COCs were selected include inorganics and PAHs. Based on the Step 3A results, lead, mercury, silver, zinc, and PAHs may pose a risk to the soil invertebrate community at Site 47. Additionally, lead, mercury, and zinc in the surface soil may pose a risk to upper trophic level receptors.

In the downgradient stream, the Step 3A results suggest COCs in a portion of the stream pose a potential risk to the benthic invertebrate and water column communities. The potential risk is primarily from mercury, silver, and one PAH (phenanthrene) in the sediments and possibly a few metals in the surface water. The area of potential risk is limited to the portion of the stream that runs along the bunkers.

3.1.1 Inorganics

Lead, mercury, silver, and zinc were selected as COCs. In Site 47 surface soil, each of these metals were identified as posing potential risks. In the stream, mercury and silver were identified as COCs in the sediment, and aluminum, iron, manganese, and zinc were identified as the COCs in the surface water. A profile for each COC is provided below.

3.1.1.1 Aluminum

Aluminum is the third most abundant element in the earth's crust and it naturally occurs primarily as a component of insoluble complex minerals (Freeman and Everhart, 1971). However, it can also be highly toxic to aquatic organisms under certain water conditions. Aluminum's toxicity is dependent on the pH, hardness, and organic content of the water. Aluminum is more soluble under both acidic and alkaline conditions, than it is under neutral conditions, with greatest toxicity observed around pH 5.5 (Freeman and Everhart, 1971). However, aluminum's toxicity may be substantially lower than is suggested by dissolved aluminum concentrations because of its complexation with humic and fulvic acids (Sample et al., 1997).

Reported chronic toxicity values for aluminum in circumneutral water to water column invertebrates include 0.74 to 38.2 mg/L for *Daphnia magna* and 1.9 to 36.9 mg/L for *Ceriodaphnia sp*. (USEPA, 1988). In *Daphnia magna*, aluminum interferes with salt regulation and can lead to death when sodium and chlorine concentrations are reduced (Havas, 1985).

Several studies have also shown that aluminum may inhibit the enzyme involved with the hatching of amphibian eggs (Sample et al., 1997).

3.1.1.2 Iron

Iron is the fourth most abundant element in the earth's crust. Iron may be present in surface water in varying quantities depending on the geology of the area and the chemistry of the water. Iron is an essential trace element required by both plants and animals. Ferrous (Fe^{2+}) and ferric (Fe^{3+}) iron are the primary forms of concern in aquatic environments. In most bodies of water, iron is present largely in the form of suspended particles, although small amounts of dissolved iron may occur as ferrous or ferric ions, and inorganic and organic complexes of both.

Dissolved iron is generally more toxic to aquatic invertebrates than it is to fish, as evidenced by the 96-hour LC_{50} values of 0.32 mg/L for mayflies, stoneflies, and caddisflies (Warnick and Bell, 1969) compared with the lethal concentration of 1 to 2 mg/L for pike (*Esox lucius*) found by Doudoroff and Katz (1953). In addition to direct toxicity, iron ions can combine with oxygen to form ferric oxide, which precipitates as a floc. Iron floc is detrimental to aquatic life because it settles to the bottom and smothers benthic invertebrates, plants, and fish eggs.

3.1.1.3 Lead

Due to the strong absorption of lead to soil organic matter, the bioavailability of lead is commonly limited. Organic compounds of lead are more bioavailable than inorganic lead. Compared to lead carbonate, lead sulfate is relatively soluble and likely to be more bioavailable. Lead can be bioaccumulated by plants and animals. The primary route of lead exposure to plants is through root uptake, though translocation to shoots is limited (Wallace et al., 1977). Biomagnification of lead has not been reported. Earthworms may bioaccumulate lead (Beyer, 1990; Roberts and Dorough, 1984), and high concentrations of lead may be toxic to earthworms, affecting both survival and rate of reproduction. Earthworm (*Eisenia fetida*) growth and survival have been shown to be reduced following exposure to soil-associated lead (as $Pb(NO)_3)_2$) for 8 weeks (Spurgeon et al., 1994). In this study, the LC_{50} and EC_{50} (coccoon production) values for *E. fetida* were 3,760 and 1,940 mg/kg, respectively. The 14-day LC_{50} value for adult *E. fetid*a exposed to lead (as $Pb(NO_3)$) in artificial soil was 5,941 mg/kg (Neuhauser et al., 1985). A 4-month study was carried out to determine the effects of lead to the earthworm (*Dendrobaena rubida*) at varying soil pH (Bengtsson et al., 1986). Following exposure to 500 mg/kg lead in soil with a pH of 4.5, the number of cocoons produced per worm, hatchlings per cocoon, and percent hatched cocoons were reduced by 75, 100, and 100 percent, respectively. No adverse effects were noted with exposure to 100 mg/kg lead at the same pH. At pH 5.5 and 6.5, no adverse effects to the earthworms were observed.

3.1.1.4 Manganese

In surface water, manganese is present at concentrations ranging from 0.001 to 0.04 mg/L (Rouleau et al., 1995, cited in Sample et al., 1997). Manganese toxicity values for *Daphnia magna,* cited in Sample et al. (1997), range from 19.4 mg/L (LC_{50}) to 4.1 mg/L (16 percent reproductive impairment). Manganese toxicity values reported for other aquatic organisms include: 16.0 mg/L (LC_{50}) for frog (*Microhyla ornata*), 28.0 mg/L (LC_{50}) for crayfish

(*Austropotamobius pallipes*), 38.7 mg/L (LC_{50}) for rotifer (*Brachionus calyciflorus*), and 130 mg/L (LC_{50}) for longfin dace (*Agosia chrysogaster*).

3.1.1.5 Mercury

The majority of mercury in soil is bound in the organic soil horizon (Lindquist et al., 1991; Steinnes, 1990). Ionic forms of mercury are bound tightly to soil by forming complexes with organic matter in the upper soil horizon (Lindquist et al., 1991). Schuster (1991) found that under acidic conditions organic matter sorbs mercury, and Lodenius (1990) found that solid organic matter in acidified soil decreases leaching of mercury by 300 percent. The dominant mercury species in soil are gaseous elemental mercury (Hg^o) and the mercuric ion (Hg^{2+}), and small amounts of monomethyl and dimethylmercury (CH_3Hg^+, $(CH_3)_2Hg$) (Revis et al., 1989; Steinnes, 1990; Schuster, 1991). The mercuric ion rarely occurs in the free ionic form under natural conditions due to its strong complexing with organic matter (Steinnes, 1990).

Survival and cocoon production in the earthworm *Octochaetus pattoni* were reduced by 65 and 40 percent, respectively, following exposure to 0.5 mg/kg mercury (Abbasi and Soni, 1983). However, exposure did not affect the number of juveniles produced. Studies have shown the effect of methylmercury to survivorship and segment regeneration in the earthworm (*Eisenia fetida*) (Beyer et al., 1985). A concentration of 12.5 mg/kg mercury reduced survival by 21 percent, and the ability to regenerate excised segments was reduced by 69 percent. Furthermore, exposure to 2.5 mg/kg methylmercury had no effect). A slug species (*Arion ater*) was used to determine the effect of mercury (as $HgCl_2$) on terrestrial mollusks (Marigomez et al., 1986). After 27 days of dietary exposure, *A. ater* displayed a 26 percent decrease in growth at 1000 mg/kg mercury, while 300 mg/kg had no effect.

In aquatic systems, sediments serve as the primary reservoir of mercury because of the strong particle reactivity of mercury. In freshwater sediments, mercury can become methylated by sulfate-reducing bacteria, particularly under anoxic conditions (Gilmour et al., 1992). Once methylated, mercury is readily taken up by organisms and is slowly depurated. Early developmental stages of organisms are the most sensitive to mercury poisoning. Methylmercury, the organic form of mercury, is the most toxic.

3.1.1.6 Silver

Silver can exist as silver nitrate, chloride, sulfide or oxide, but primarily exists in the sulfide form (ATSDR, 1990). Subsequently, transport in the environment depends on it particular compound form. Silver adheres strongly to clay particles found in suspended particulates and sediments. In aquatic environments the most commonly occurring forms of silver are silver (I) (soluble form), bicarbonate and sulfate salts, or complexations with particulates (ATSDR, 1990). In soils, silver tends to form complexes with inorganic chemicals and humic substances. As pH increases, silver solubility increases and subsequently mobility increases. Silver is toxic to microbial communities and inhibits bacterial enzymes, therefore biotransformation is not expected to be significant (ATSDR, 1990).

In aquatic systems, the impact of silver is most likely to occur in the sediment/water interface. It is acutely toxic to scuds (small freshwater crustaceans) at <6 μg/L and midges (fly larvae that inhabit freshwater sediments) at <5 μg/L. Aquatic invertebrates, such as various water flea species (*Daphnia magna* and *Daphnia pulex*) have displayed adverse effects from acute silver exposure. Following 2 days of exposure, the LC_{50} value for *D. magna* was

9.5 µg/L (Chapman et al., 1980) and the LC_{50} value for *D. pulex* was 14.0 µg/L (Mount and Norberg, 1984). Currently, there are no established sediment quality guidelines (SQGs) for silver in freshwater sediments, except for the upper effects threshold (UET) of 4.5 mg/kg that is based on the results of *Hyalella azteca* bioassays (Buchman, 1999).

3.1.1.7 Zinc

In the environment, the most common form of zinc is in the +2 oxidation state. Zinc is highly reactive in soils and can be adsorbed to clay minerals or metallic oxides (Sachdev et al., 1992). The active zinc species in the adsorbed state is the singly charged zinc hydroxide species (i.e., Zn(OH) +) (Sanders and El Kherbawy, 1987). This metal forms stable complexes with organic substances such as humic and fulvic acids. Metallic zinc is insoluble, but the solubilities of zinc compounds range from insoluble (oxides, carbonates, phosphates, silicates) to extremely soluble (sulphates and chlorides) (Environment Canada, 1996).

Zinc solubility and mobility increases with decreasing soil pH. In soils with pH > 7.7, $Zn(OH)_2$ becomes the dominant form and solubility is very low. Zinc in a soluble form, such as zinc sulfate, is fairly mobile in most soils. However, relatively little zinc in most soils is in soluble form, and mobility is, therefore, limited by a slow rate of dissolution. Low pH (<7) and high ionic strength of the leaching solution favor desorption (USEPA, 1987; Saeed and Fox, 1977).

Eisenia fetida exposed to zinc (as zinc nitrate) exhibited lethal and sublethal (e.g., growth effects) effects (Spurgeon and Hopkin, 1995). Zinc exposure resulted in estimated LC_{50} and EC_{50} (growth) values of 216 and 400 mg/kg, respectively. Further studies evaluating the effects of zinc (as zinc acetate) in horse manure to *E. fetida*, showed reduced cocoon production (Malecki et al., 1982). Following an 8-week exposure, 2,000 mg/kg resulted in a 36 percent decrease in cocoon production, while 1,000 mg/kg had no effects. Following a 20-week exposure, 5,000 mg/kg resulted in a 53 percent reduction in cocoon production, while 2,500 mg/kg had no effect. Following zinc exposure in soil, the terrestrial isopod, *Porcellio scaber* exhibited prolonged molting (Drobne and Strus, 1996). The NOEL for *P. scaber* molting was 250 mg/Kg.

Zinc toxicity to earthworms (*Eisenia fetid*a) was evaluated through studies with a range of artificial soils having varying organic content and pH (Spurgeon and Hopkin, 1996). In general, mortality increased as zinc concentrations increased, and a decrease in pH and organic matter (i.e., within the range tested) tended to decrease zinc toxicity. Depending on soil chemistry, the estimated EC_{50} values (cocoon production) for this study ranged from 136 to 592 mg/kg. Studies in which adult earthworms *(E. fetid*a) were exposed to zinc (as $Zn(NO_3)$) in artificial soil (pH 6) were used to estimate LC_{50} values (Neuhauser et al., 1985). Following 14 days of exposure, an LC_{50} value of 662 mg/kg was calculated.

In aquatic systems low alkalinity, low hardness, and high pH promote the formation of bioavailable species of zinc (Paulauskis and Winner, 1988; Schubauer-Berigan et al., 1993). Zinc is an essential trace element to both plants and animals. The amount of bioavailable zinc will be determined by the amount of zinc present, and in what form it exists (e.g., soluble or insoluble). Zinc is more bioavailable in acidic soil conditions, particularly at pH less than 5 (Duquette and Henershot, 1990).

Studies using a variety of benthic macroinvertebrates species have been used to document the effects of zinc exposure in the aquatic environment. Two water flea species were exposed to zinc for 2 days and have shown somewhat varying sensitivities. The 2-day LC_{50} values for *Ceriodaphnia dubia* and *Daphnia magna* were 0.13 (Belanger and Cheery, 1990) and 1.59 mg/L (Kazlauskiene et al., 1994), respectively. In a 3-day study where common toad (*Bufo arenarum*) tadpoles were exposed to a range of zinc levels (i.e., 4-32 mg/L), 65 percent mortality resulted at the 32 mg/L exposure level (Herkovits and Perez-Coll, 1991). Twenty four hours of exposure to 39 mg/L zinc resulted in 100 percent mortality for Western toad (*Bufo boreas*) larvae, while all larvae still metamorphosed following exposure to 0.1 mg/L over the same time period (Porter and Hakanson, 1976). Exposure to 15 mg/L of $ZnSO_4$ yielded no toxicity for African clawed frog (*Xenopus laevis*) tadpoles (Woodall et al., 1988), while exposure to 20 mg/L resulted in 4-15 percent mortality.

3.1.2 Polynuclear Aromatic Hydrocarbons

PAHs were identified as COCs in surface soil near Building 856 and at the suspected chemical disposal area. An individual PAH (phenanthrene) was also identified as a COC in the stream sediments.

Most animals and microorganisms can metabolize and transform PAHs to breakdown products that may ultimately experience complete degradation. PAHs with high molecular weights are degraded slowly by microbes and readily by multicellular organisms. Biodegradation probably occurs more slowly in aquatic systems than in soil.

PAHs of all sizes show little tendency for long-term bioaccumulation despite their high lipid solubility, probably because most PAHs are rapidly and extensively metabolized. Bioaccumulation is thus not considered an important fate in most multicellular organisms because it is usually a temporary process. Large interspecies differences in the ability to absorb and assimilate PAHs from food have been reported for aquatic organisms. In all cases where assimilation of ingested PAHs has been demonstrated, metabolism and excretion of PAHs was rapid. Thus, little potential exists for the accumulation of PAHs in food webs, at least in aquatic systems.

PAHs are moderately persistent in the environment and therefore may potentially cause significant effects to vegetation and wildlife. The carcinogenicity of individual PAHs differs. Some lower weight compounds such as naphthalene, fluorenes, phenanthrenes, and anthracenes exhibit acute toxicity and other adverse effects to some organisms, but are non-carcinogenic. In contrast, the higher molecular weight compounds are significantly less acutely toxic, but many are demonstrably carcinogenic, mutagenic, or teratogenic to a wide variety of organisms, including fish and other aquatic life, amphibians, birds, and mammals.

In aquatic environments, PAHs rapidly become adsorbed to organic and inorganic particulate materials and are deposited in sediments (Neff, 1985). Once adsorbed to sediment, PAHs have limited bioavailability to aquatic organisms (Neff, 1985). However, PAHs deposited in sediments can be toxic to benthic invertebrates. In sediment toxicity tests with the tubificid, *Limnodrilus hoffmeisteri*, Lotufo and Fleeger (1996) observed a median lethal phenanthrene level of 298 mg/kg (sediment organic carbon content = 0.7 percent). Decreases in tubificid reproduction were observed at much lower levels; IC_{25} s

(concentration associated with a 25 percent inhibition in measured endpoint relative to control) of 40.5 mg/kg for phenanthrene.

In aquatic environments, exposure to ultraviolet light can result in photomodification of some PAHs to products with increased polarity, water solubility, and toxicity compared to the parent compound (Duxbury et al., 1997). Ireland et al. (1996) showed that the photoinduced toxicity of PAHs to the daphnid, *Ceriodaphnia dubia*, occurred frequently during low-flow conditions and wet weather runoff, and was reduced in turbid conditions. In studies on the marine amphipod, *Rhepoxynius abronius*, ultraviolet radiation exposure enhanced the toxicity of fluoranthene and pyrene in sediments, but did not affect the toxicity of phenanthrene (Swartz et al., 1997).

3.2 Conceptual Model

Information on the habitat features of the site, and the fate and transport of the COCs, are used to build the conceptual model (Figure 3-1). The conceptual model addresses complete exposure pathways, receptors, assessment endpoints, measurement endpoints, and risk hypotheses/questions. It has been revised to reflect the results of the SERA and Step 3A.

3.2.1 Exposure Pathways

Chemical sources at this site include historical chemical releases in the vicinity of Building 856. Receptors include soil invertebrates and terrestrial wildlife in the upland portion of the site and benthic invertebrates, water column invertebrates, and amphibians in the downgradient stream. Receptors may be exposed to chemicals via direct contact with abiotic media, ingestion, or trophic transfer through the foodchain.

The data gathered to date suggest that concentrations of lead, mercury, silver, zinc, and PAHs are elevated in surface soils at Site 47, possibly due to past disposal activities (mercury is known to be present from past disposal). The data further suggest that some contaminant transport has occurred through surface runoff along the main drainage ditch and into the stream downgradient of the site, as identified by the elevated concentrations of mercury and silver in the stream sediments. Additional evidence of possible contaminant migration is the concentrations of zinc measured in surface water from the stream. The extent of contaminant migration appears to be limited however, as the furthest down-gradient sample (off the western edge of Caffee Road) contained concentrations of COCs below risk screening levels. The reach of the stream downstream of Caffee Road was remediated for mercury contamination associated with Site 8 in 1994. Excavated areas of Site 8 and the stream were backfilled with common fill and riprap. The remediation affected a 300-ft section of the stream where mercury concentrations exceeded the 10-mg/kg action level established for the removal action. Therefore, although site-related chemicals from Site 47 may have been transported beyond Caffee Road, the removal action conducted for Site 8 would have remediated any Site 47-related chemicals in the sediments as well. The remediated section of the stream adjacent to Site 8 is now comprised of a riprap channel that conveys intermittent flows. Under most conditions surface water from upstream of Caffee Road moves downstream via interstitial flow through the riprap section of the stream adjacent to Site 8.

3.2.2 Assessment Endpoints

Refined assessment endpoints for the BERA are as follows:

Survival and growth of soil invertebrates. Soil invertebrates serve as a forage base for many terrestrial species. The soils at the site will support fewer birds and mammals if chemical concentrations are limiting the survival, growth, and reproduction of soil invertebrates.

Survival, growth, and reproduction of benthic invertebrates. Healthy, viable benthic invertebrate communities are necessary for a well-developed and balanced aquatic ecosystem. Benthic invertebrates influence nutrient cycling and availability, and sediment condition. By serving as prey species for many upper trophic predators, they are critical to the sustenance of the communities of upper trophic level species.

Protection of larval amphibians and water column invertebrates from adverse effects of aluminum, iron, manganese, and zinc. Larval amphibians and water column invertebrates are susceptible to direct chemical exposure. Water column invertebrates are an important part of aquatic foodwebs, providing a link between primary production and upper trophic levels of the foodweb. Amphibians are a vital component to a balanced aquatic ecosystem.

Survival, growth, and reproduction of insectivorous birds. These receptors are 3rd order consumers and are thus more susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify. American robin (*Turdus migratorius*) was chosen to represent this endpoint. Robins live in a variety of habitats, including woodlands, swamps, suburbs, and parks. They forage on the ground in open areas, along edge habitats, or along the edges of streams. Robins forage for ground-dwelling invertebrates and search for fruit and foliage-dwelling insects in low tree branches (Malmborg and Willson, 1988). Since robins forage for soil invertebrates, their exposure to soil contamination would likely be significant.

Survival, growth, and reproduction of herbivorous birds. These receptors are second-order consumers that are susceptible to chemicals that bioaccumulate in plants, and to chemicals adsorbed to soil particles. The mourning dove (*Zenaida macroura*) was chosen to represent this endpoint**.** The mourning dove is common in open grassland habitats and feeds almost exclusively on cereal grains, forbs, and grasses. Similar to the robin, the mourning dove is expected to have significant contact with soil. Lead was the only COC identified as posing a potential risk to herbivorous birds. Since potential risk from lead to insectivorous birds is being evaluated in the BERA and insectivorous birds are at a higher trophic level than are herbivorous birds, it is assumed that the measurement endpoint selected for insectivorous birds will allow an adequate evaluation of potential risk to herbivorous birds as well.

Survival, growth, and reproduction of omnivorous terrestrial mammals. These receptors are second-order consumers and are thus more susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify. The white-footed mouse (*Peromyscus leucopus*) was chosen to represent this endpoint. The white-footed mouse inhabits nearly all types of dry-land habitats within their range (Burt and Grossenheider, 1980). They are opportunistic feeders and eat seeds, arthropods, some green vegetation, roots, and fruit.

3.2.3 Risk Hypotheses

Risk hypotheses are questions about how assessment endpoints could be affected. Risk hypotheses clarify and articulate relationships that are possible through consideration of available data, information from the scientific literature, and the best professional judgement of risk assessors. The risk hypotheses/questions associated with the assessment endpoints are:

1. Are the concentrations of lead, mercury, silver, zinc, and PAHs in surface soil at Site 47 impairing the survival and growth of soil invertebrate communities to the extent that the prey base to support terrestrial insectivores has been adversely affected?
2. Are the concentrations of mercury, silver, and phenanthrene in the sediment impairing the survival, growth, or reproduction of benthic invertebrates in the stream independent of the limitations of the marginal habitat?
3. Are the concentrations of aluminum, iron, manganese, and zinc in surface water high enough to cause adverse effects to water column invertebrates or larval amphibians in the stream?
4. Is lead, mercury, or zinc in the surface soil at Site 47 bioaccumulating in soil invertebrates to the extent that the growth, survival, or reproduction of omnivorous terrestrial mammals and insectivorous and herbivorous birds that forage at the site may be impaired?

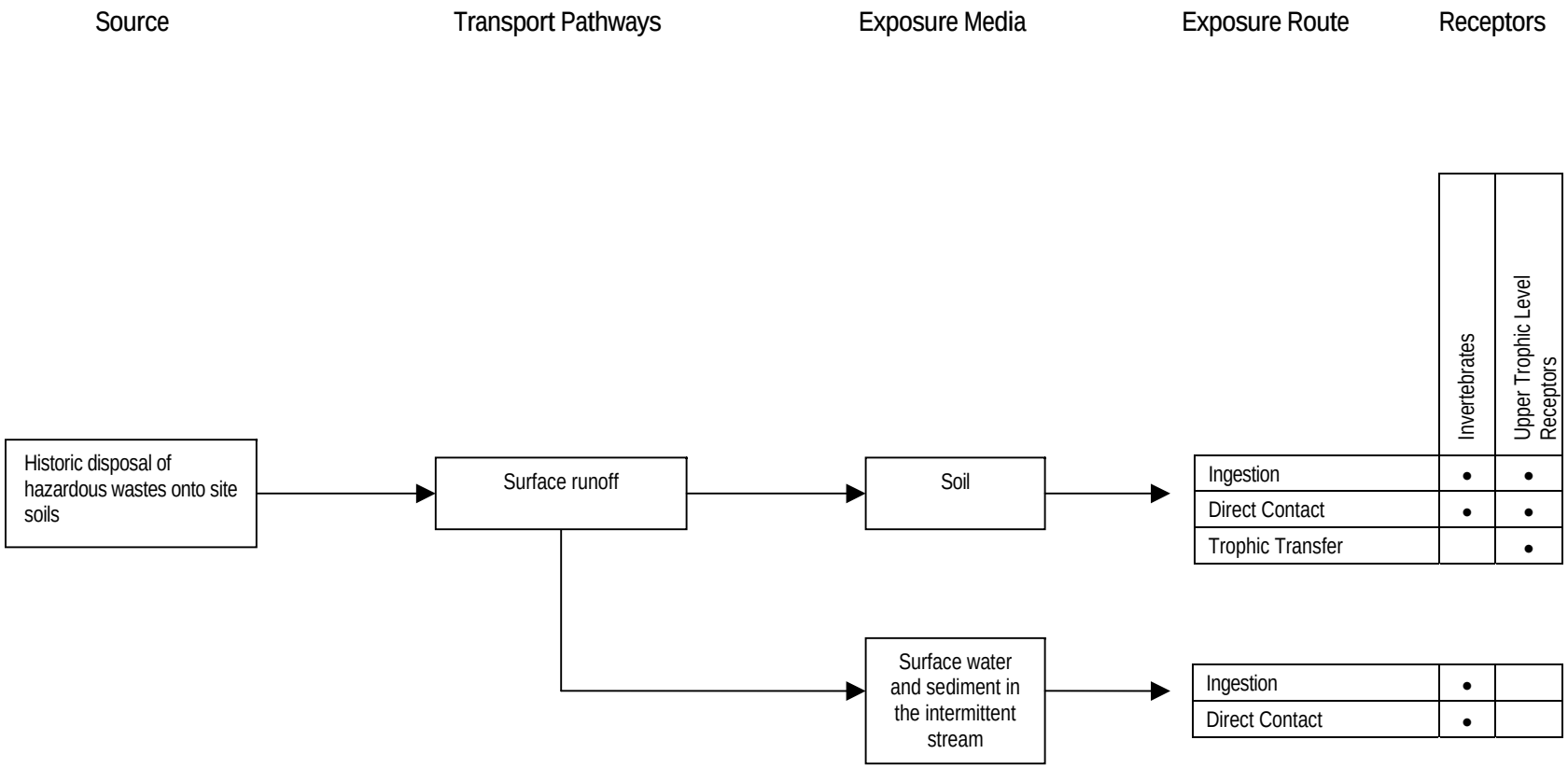


Figure 3-1
Conceptual Site Model
Baseline Ecological Risk Assessment
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

SECTION 4

Step 4: Study Design / Data Quality Objectives

Step 4 of the ERA establishes the measurement endpoints, the study design, and data quality objectives for the additional site investigations necessary to complete the ecological risk assessment (USEPA, 1997). Another element of Step 4 is the sampling and analysis plan, which is provided in Section 5 of this document. The field sampling is designed to address areas identified as having the greatest potential risk and/or degree of uncertainty in earlier steps of the ERA process.

4.1 Measurement Endpoints

Measurement endpoints are measures of biological effects (e.g., laboratory toxicity test results) that are related to each respective assessment endpoint (USEPA, 1997). For the areas of concern at Site 47, measurement endpoints associated with each assessment endpoint are defined as follows:

Assessment Endpoints	Measurement Endpoints
Survival and growth of soil invertebrate communities.	Comparison of results of 28-day soil toxicity tests (survival and growth) with the earthworm, *Eisenia foetida*, using site, reference, and control soils. Existence of significant correlations between laboratory toxicity test results and concentrations of COCs in site soil.
Survival, growth, and reproduction of benthic invertebrate communities.	Comparison of results of 42-day sediment laboratory toxicity tests (growth, survival, and reproduction) with the amphipod, *Hyalella azteca*, using site, reference, and control sediment. Existence of significant correlations between laboratory toxicity test results and concentrations of COCs in site sediments.
Survival, growth, and reproduction of water column receptors.	Comparison of the ratio between mean concentrations of COCs (from filtered samples) and Ambient Water Quality Criteria to a reference HQ of 1.0.
Survival, growth, and reproduction of birds and mammals that feed on soil invertebrates at the site.	Comparison of estimated exposure dose to toxicity reference value using site-specific bioaccumulation data obtained from lead, mercury, and zinc concentrations in earthworm tissue (from soil bioassays) to a reference HQ of 1.0.

4.2 Study Design

This section presents the scope of the additional sampling planned for Site 47 to address potential risks and uncertainties in the ERA. A detailed description of the proposed sampling activities and analyses is presented in Section 5 (Sampling and Analysis Plan).

4.2.1 Toxicity Testing

To evaluate direct toxicity to soil and benthic invertebrates, laboratory toxicity tests will be conducted on split samples from soil and sediment sampling locations. At each location, sufficient sample volume to conduct the tests will be homogenized in the field prior to filling bottles for chemical and toxicological analysis.

Eisenia foetida (*E. foetida*) (earthworm) will be used for soil toxicity testing. This organism was selected over *Lumbriculus terrestris* (*L. terrestris*), another earthworm species commonly used in soil toxicity testing, because there are more test data available on *E. foetida* than on *L. terrestris.* In addition, *L. terrestris* is intolerant of nonloamy soils, and toxicity-testing laboratories sometimes experience difficulty meeting control performance criteria with this organism (Jim Hoberg, Springborn Laboratories, personal communication).

Hyalella azteca (*H. azteca*) (amphipod) will be used for sediment toxicity testing. This organism was selected because its use is widely accepted it is tolerant of a wide range of grain sizes, and quality information on reproduction can be obtained during a 42-day test.

Each test will provide information on growth and survival, and the sediment tests will also provide information on reproduction. Chemical analyses of soil and sediment will support the toxicological analyses. A control will be run for each organism to ensure that the population used in the toxicity testing is healthy. Good health is demonstrated when the organism's performance meets or exceeds some threshold (e.g., 80 percent survival). The toxicity testing laboratory will determine the appropriate substrate for control testing.

To better evaluate potential risk to water column invertebrates and larval amphibians, surface water samples will be collected and analyzed for dissolved aluminum, iron, manganese, and zinc.

4.2.2 Sample Locations

The spatial distribution of screening value exceedences for each COC was evaluated to determine the locations for laboratory toxicity tests with site soils. The spatial distribution of the COCs in surface soil near Building 856 was discussed in Section 2.3.1. Based on this evaluation, 10 surface soil sample locations were identified for soil toxicity testing to characterize the potential risk to the soil invertebrate community in the vicinity of Building 856. The proposed soil sampling locations for soil toxicity testing are shown in Figure 4-1.

The 10 locations for soil toxicity testing were chosen to develop an exposure-response gradient. The locations were selected so that a range of COC concentrations, from the areas with the highest exceedences to areas with minimal to no screening value exceedences. The intent is to identify: (1) if there is a significant difference in survival or growth in site soils relative to reference and control soils (control soil will be used to check the health of the test organisms and appropriateness of the test species), and (2) if there is a significant difference, can a toxic threshold concentration be identified for a given COC or mixture of COCs that can be used to aid in future risk management decisions for the site. Soil will be collected for the toxicity testing from a depth of 0 to 6 in., which will capture the bulk of the biologically active zone because the A and O soil horizons at the site are thin and not well developed.

The surface soil locations selected for toxicity testing include:

	Hazard Quotients				
Sample ID	**Lead**	**Mercury**	**Silver**	**Zinc**	**Total PAHs**
IS47SS02	19.6	474.0	20.2	15.2	1.2
IS47SD01	5.8	29.0	407.0	7.4	1.3
IS47SS06	26.2	55.0	237.0	1.9	1.4
IS47SS14	2.2	2.2	106.0	5.3	< 1.0
IS47SD02	1.5	1.5	20.3	ND	6.2
IS47SS10	1.8	9.9	3.0	5.1	2.2
IS47SS12	< 1.0	6.5	< 1.0	ND	< 1.0
IS47SD04	< 1.0	2.1	1.8	ND	< 1.0
IS47SA08	< 1.0	< 1.0	1.7	< 1.0	< 1.0
IS47SS04	< 1.0	1.4	< 1.0	ND	< 1.0

A short section of the stream (north of sampling location IS47SD05) was identified as containing concentrations of chemicals that may pose a risk to benthic invertebrates. In the sediment within this reach of the stream, two metals (mercury and silver) and one PAH (phenanthrene) were identified as COCs for the benthic community. None of the chemicals detected in the sediment samples downstream of sample IS47SD05 were present at concentrations exceeding the screening values. To further evaluate this potential risk, bulk sediment toxicity testing will be conducted at two locations in this reach of the stream. The sediment toxicity testing will be conducted at locations IS47SS17 and IS47SD05 (Figure 4-2). These two locations contained the highest concentrations of mercury, silver, and phenanthrene in the sediment samples. Sediment samples will be collected from a depth of 0 to 6 in. below the sediment/water interface to ensure that the bulk of the biologically active zone is captured.

It is likely that the potential risk identified from metals in surface water of the stream is overestimated. Therefore, to further evaluate the potential risk posed by metals in the stream, the previous surface water sampling locations (IS47SW01 and IS47SW02) will be sampled again and analyzed for both total and dissolved metals.

4.2.3 Reference Samples

The response of organisms to reference soil and sediment will be statistically compared to the response of organisms exposed to site soil and sediment. The response of organisms to control soil and sediment will also be compared with the response to site and reference soil and sediment in evaluating the results of the toxicity tests. Care will be taken to collect reference soil and sediment that has similar physical characteristics as the soil and sediment at the site. The similarities and differences between each reference area and the group of samples it is used for will be described and presented in the BERA report.

The soil reference site will likely be one of the sampling locations used in the Background Soil Investigation Report for NDWIH (Tetra Tech NUS, 2002). One of the background sampling locations (BGDSS03) is located in an undeveloped, wooded area approximately 3,500 ft southwest of Site 47. Soil from the reference site will be analyzed for the same parameters as the site samples. If the physical characteristics of the soil at this location are not consistent with those at Site 47, or if more than one soil type is needed for the reference soil, then additional locations will be investigated as potential reference sites.

The sediment reference location will be selected from the existing freshwater sediment sampling location used in the Indian Head Background Investigation Report (Tetra Tech NUS, 2002). Care will be taken to ensure that the reference sediment closely resembles the physical characteristics of the site sediment (i.e., similar grain size and amount of organic material). If a representative reference location is unavailable, a known area of minimal contamination in the vicinity of the site samples will be used as the reference (e.g., IS47SS18).

4.3 Data Quality Objectives

The data quality objective (DQO) process provides a procedure for defining the criteria that a study design should satisfy. The steps of the DQO process are: Step 1 (State the Problem), Step 2 (Identify the Decision), Step 3 (Identify Inputs to the Decision), Step 4 (Define the Study Boundaries), Step 5 (Develop Decision Rules), Step 6 (Specify Limits on Decision Errors), and Step 7 (Optimize the Design for Obtaining Data). Because ecological risk assessments are weight-of-evidence-based, the last three steps of the DQO cannot be applied fully to ecological risk assessments. Weight-of-evidence evaluations often involve different types of measurements, ranging from contaminant concentrations to toxicity test results, probabilistic hypotheses with confidence limits cannot be formulated, and therefore simple optimization rules cannot be followed (Barnthouse and Suter, 1996). The steps of the DQO process for the Site 47 BERA investigation are described below.

4.3.1.1 Step 1. State the Problem

Mercuric nitrate was used in Building 856 at Site 47 as a catalyst in the production of the missile propellant hydrazinium nitroformate and was disposed of at a location near the southeastern corner of the building. An estimated 274 pounds of mercuric nitrate were disposed of at the site between 1957 and 1965 (NEESA, 1988). The data gathered to date suggest that concentrations of lead, mercury, silver, zinc, and PAHs are elevated in surface soils at the site, possibly due to past disposal activities (mercury is known to be present from past disposal). The data further suggest that some contaminant transport has occurred through surface runoff along the main drainage ditch and into the stream downgradient of the site, as identified by the elevated concentrations of mercury and silver in the stream sediments. Additional evidence of possible contaminant migration is the concentrations of zinc measured in surface water from the stream. Evaluation of the data collected to date indicates that potential risks exist to soil invertebrates from lead, mercury, silver, zinc, and PAHs, to benthic invertebrates from mercury, silver, and phenenthrene, to water column invertebrates from aluminum, iron, manganese, and zinc, and to upper trophic level receptors from lead, mercury, and zinc.

4.3.1.2 Step 2. Identify the Decisions

Primary Question:

What are the potential ecological risks related to COCs in surface soil around Building 856 and in the surface water and sediment in the downgradient stream at Site 47?

Secondary Questions:

Are the chemical constituents in the surface soil toxic to the soil invertebrate community?

Are the chemical constituents in the sediment toxic to the benthic invertebrate community?

Are the chemical constituents in the surface water toxic to water column invertebrates and larval amphibians?

Are lead, mercury, and zinc bioaccumulating in soil invertebrates to the extent to pose a risk to birds and mammals that forage at the site?

4.3.1.3 Step 3. Identify Inputs to the Decision

1. Results of previous sediment sampling events
   - Lead, mercury, silver, zinc, and PAHs are elevated relative to background and pose potentially unacceptable ecological risk.
2. Soil and sediment toxicity testing (risk to invertebrate communities)
   - Soil and sediment chemistry
   - Bulk soil and sediment toxicity
3. Tissue Analysis
   - COC residues in earthworm tissue (obtained from bioassays)
4. ERA models
   - COC residues measured in earthworm tissue will be used to replace modeled values used in Step 3A to estimate risk to upper trophic level receptors, including American robin (avian insectivore) and white-footed mouse (mammalian omnivore). If results indicate no unacceptable risks for robin, then results will be used as evidence that no unacceptable risk exists to herbivorous birds as well, because herbivorous birds are lower in trophic level than are insectivorous birds.

4.3.1.4 Step 4. Define the Study Boundaries

1. COCs in soil include lead, mercury, silver, zinc, and PAHs. COCs in sediment include mercury, silver, and phenanthrene. COCs in surface water include aluminum, iron, manganese, and zinc. COCs for upper trophic level receptors include lead, mercury, and zinc.

2. Sampling depth for soil and sediment will be 0–6 in., an estimate of the biologically active zone. Consumption of soil invertebrates by higher-trophic-level consumers can facilitate movement of soil contamination through the food chain.

3. The soil and sediment reference areas are defined by using the sampling locations used in the Background Investigation Report for NDWIH (Tetra Tech NUS, 2002). One of the background sampling locations (BGDSS03) is located in an undeveloped, wooded area approximately 3,500 ft southwest of Site 47. The sediment reference location will be selected from the existing freshwater sediment sampling location used in the Background Investigation Report.

4.3.1.5 Step 5. Develop Decision Rules

Soil Invertebrate Community. The following criteria will be used to weigh the results of the soil toxicity testing effort to assess potential risk to the soil invertebrate community.

- **Bulk Soil Toxicity.** The growth and survival of test organisms in site soil will be statistically compared with the results of these parameters from reference and control soil. If significant (alpha level of 0.05) adverse effects are found, the soil will be considered toxic at a given station. If no significant adverse effects are found in any of the samples, then the soil will be considered nontoxic to the soil invertebrate community.

- **Soil Chemistry.** If significant adverse effects are found in the site soil tests, then associations between biological and chemical data will be evaluated by examining the relationship between effects and COC concentrations. The sampling scheme is designed to produce a gradient of COC concentrations so that a toxicity threshold can be identified for the driver COCs from the results of the toxicity testing, which can be used to support development of cleanup goals for the site, if warranted.

Benthic Invertebrate Community. The following criteria will be used to weigh the results of the toxicity testing effort to assess potential risk to the benthic invertebrate community.

- **Bulk Sediment Toxicity**. The growth, survival, and reproduction of test organisms in site sediment will be statistically compared with the results of these parameters from reference and control sediment. If significant (alpha level of 0.05) adverse effects are found, the sediments will be considered toxic at a given station

- **Sediment Chemistry.** If significant adverse effects are found in the site tests, then associations between biological and chemical data will be evaluated by examining the relationship between effects and COC concentrations to identify the COC(s) likely driving the toxicity. Given the small reach of the intermittent stream where potential risk was identified, no attempt was made to establish a COC concentration gradient similar to the upland soils. Thus, the outcome of the sediment evaluation will be a conclusion that the sediments in the affected reach are either toxic or nontoxic to the benthic invertebrate community.

Water Column Invertebrate and Larval Amphibian Communities. The following criteria will be used to weigh the results of the sampling effort to assess potential risk to the water column invertebrate and larval amphibian communities.

- **Water Chemistry.** Filtered and nonfiltered surface water samples will be collected to gain a better understanding of potential risk to these communities. It is possible that the previous water samples were collected under disturbed conditions with increased suspended solids, thus leading to an overestimation of potential risk. Additionally, it is likely that the potential risk identified for aluminum, iron, and manganese is reflective of background geologic conditions, since none of these were identified as COCs for the upland soils. The potential risk identified for zinc may be directly related to elevated zinc concentrations in the soils at Site 47. If a potential risk is identified for zinc after the second round of surface water sampling, then it will be concluded that a potential risk exists to these communities in the downgradient stream. However, further evaluation to refine this risk should await the outcome of the risk evaluation for the upland soils and any remedial action (source control), if warranted. Thus, any further surface water investigation could possibly be limited to future sampling to verify that off-site migration to the stream has been controlled, and thus the risk to the water column invertebrate and larval amphibian communities mitigated.

Upper Trophic Level Receptors. The following criteria will be used to weigh the results of the sampling effort to assess potential risk to upper trophic level receptors that may forage on soil invertebrates at Site 47.

- **Invertebrate Tissue Analysis.** The COCs measured in the earthworm tissue from the bulk soil toxicity tests will be used to model exposure to insectivorous birds and omnivorous mammals. Unacceptable risk will be constituted by exceedance of LOAEL-based reference toxicity values for these receptors. The conclusions for insectivorous birds will be considered applicable for herbivorous birds as well because they are lower trophic level receptors than are insectivorous birds and thus are likely less exposed to lead than are birds that feed on soil invertebrates. If unacceptable risks are identified for these receptors, then the site-specific bioaccumulation data derived from these tests will be used in conjunction with the bulk soil toxicity data in deriving a toxicity threshold to support any remedial cleanup goals for the site, if warranted.

4.3.1.6 Step 6. Evaluate Decision Errors

The intent of this data collection effort is to reduce uncertainty in the risk estimates arrived at after the conclusion of Step 3A. The results of this effort will determine the baseline ecological risk posed by COCs in the media at Site 47.

Baseline Decision Rule Errors:

- Deciding that the COCs in the media at Site 47 are not toxic to ecological receptor when, in fact, they are toxic and are potentially causing harm to ecological receptors. The consequence of this error is failing to proceed with remediation when an unacceptable risk is present.

- Deciding that the COCs in the media at Site 47 are toxic to ecological receptors and potentially causing harm when, in fact, they are not toxic to ecological receptors. The

consequence of making the error is deciding to proceed with remediation when there is no unacceptable risk. The level of significance that will be used to evaluate the data (i.e., the probability of making this error) is $\alpha = 0.05$.

4.3.1.7 Step 7. Optimize the Design for Obtaining Data

The study design for obtaining the data to reduce the uncertainties surrounding the risk conclusions at Site 47 was described in Section 4.2. The uncertainty in the risk to the soil invertebrate and benthic invertebrate communities will be reduced through the results of the toxicity testing. The uncertainty in the risk estimates for upper trophic level receptors will be greatly reduced by developing site-specific bioaccumulation data from the COC residues in earthworms used in the bulk soil toxicity tests. These data will provide more accurate estimates of the bioavailability and bioaccumulation potential of COCs in the soils, rather than relying on bioaccumulation factors from the literature. Therefore the outcome of this effort should provide a realistic baseline estimate of potential ecological risk to upper trophic level receptors that forage at the site.

Necessary detection limits for metals and PAHs in the media at the site are based on ecological screening criteria. Detection limits should remain below the chemical-specific screening criteria for metals and PAHs.

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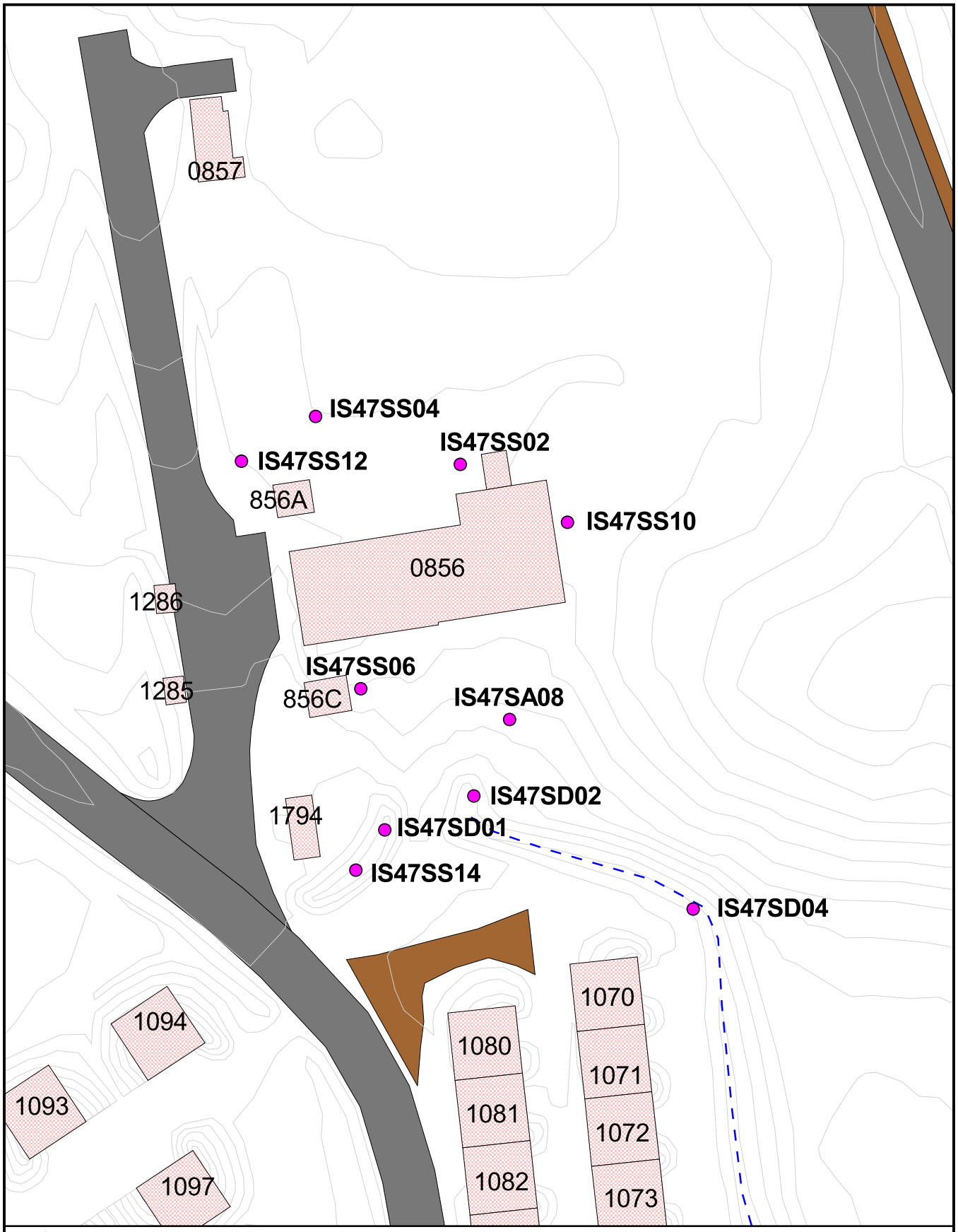

LEGEND

- Toxicity Test Location
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

N

0 25 50 Feet

Figure 4-1
Proposed Surface Soil Toxicity Test
Locations near Building 856
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

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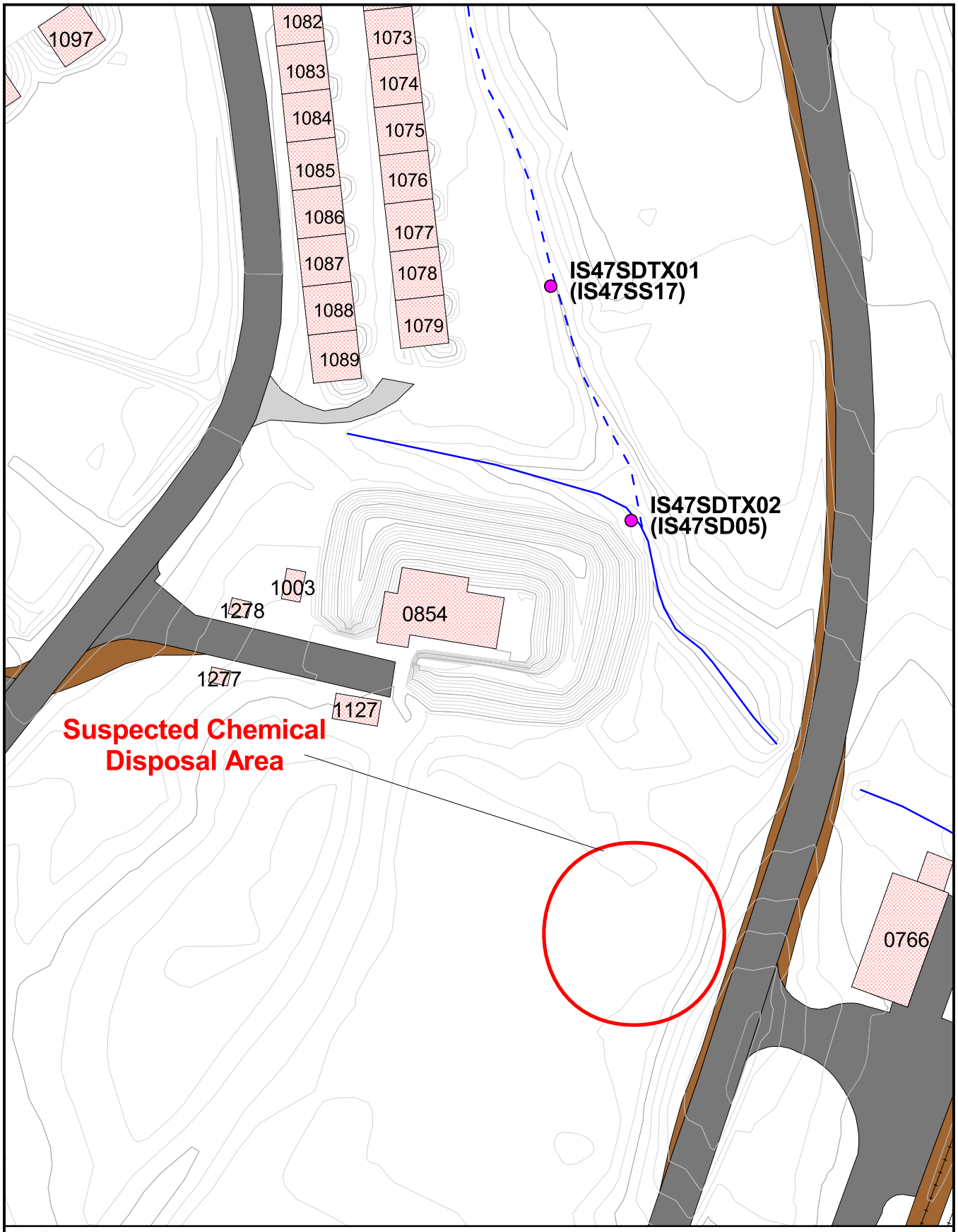

LEGEND

- Toxicity Test Location
- Buildings
- 1 Foot Contours
- Drainage Ditch
- Asphalt

N

0 35 70 Feet

Figure 4-2
Proposed Toxicity Test Locations in the Stream and at the Suspected Chemical Disposal Area
Site 47 BERA Work Plan
NDWIH, Indian Head, Maryland

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SECTION 5

Sampling and Analysis Plan

The Sampling and Analysis Plan is comprised of two components: the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP). The FSP provides detailed descriptions of the sampling activities and procedures that will be used to meet the objectives of this work plan. The QAPP provides a description of the quality control procedures that will be used ensure that the data collected meet the DQOs of this work plan.

5.1 Field Sampling Plan

5.1.1 Surface Soil (Building 856)

Surface soil will be collected from 10 locations at Site 47 from the area surrounding Building 856, as described in Section 4.2.2 (Figure 4-1). The samples will be collected from 0 to 6 in. below ground surface (bgs) with a decontaminated trowel or shovel. Approximately 8 L of soil will be collected and placed in a decontaminated stainless steel bowl and homogenized.

The surface soil samples will be submitted for toxicity testing and chemical analysis. The soil chemistry sample containers will be filled and the remainder of the soil will be placed in the sample containers provided by the bioassay laboratory.

A 28-day soil toxicity test with the earthworm *E. foetida* will be conducted for each sample. At the conclusion of the 28-day tests, the earthworm tissue from each test will be analyzed for lead, mercury, zinc, and percent moisture to provide site-specific bioaccumulation data for these metals. The chemistry samples will be analyzed for PAHs (SIM method), TAL metals, pH, TOC, and grain size (by sieve analysis).

5.1.2 Surface Water and Sediment in the Drainage Ditch/Stream

Sediment will be collected from two locations in the stream for bulk sediment toxicity tests and chemical analysis. The proposed sampling locations are shown in Figure 4-2. The samples will be collected from depositional areas in the vicinity of the previous sampling locations (IS47SS17 and IS47SD05).

The samples will be collected from 0 to 6 in. below the sediment/water interface with a decontaminated trowel or auger. Approximately 8 L of sediment will be collected and homogenized in a decontaminated stainless steel bowl. The sediment chemistry sample containers will be filled and the remainder of the sediment will be placed in the sample containers provided by the bioassay laboratory.

A 42-day bulk sediment toxicity test with the amphipod *H. azteca* will be conducted for each sample. Ammonia concentrations will be monitored during the toxicity tests to ensure that ammonia buildup does not confound the test results. The chemistry samples will be analyzed for PAHs (SIM method), TAL metals, TOC, and grain size (by sieve analysis).

Sediment pH and oxidation-reduction potential (ORP) will be measured in-situ, if possible, at each sampling location with a pH and ORP meter and recorded in a field log book.

Two surface water samples will also be collected from the stream at the same locations where the sediment samples are collected (Figure 4-2). The samples will be analyzed for total and dissolved TAL metals, hardness, pH, and dissolved organic carbon (DOC). Dissolved metals samples will be field-filtered using a peristaltic pump and 45-µm in-line disposable filters.

5.1.3 Reference Soil and Sediment Samples

The soil reference location will likely be one of the locations sampled as part of the *Background Soil Investigation Report for Indian Head and Stump Neck Annex Naval Surface Warfare Center* (Tetra Tech NUS, 2002) (herein referred to as the Background Soil Investigation Report). One of the background sampling locations (BGDSS03) is located in an undeveloped, wooded area approximately 3,500 ft southwest of Site 47. If the physical characteristics of the soil at this location are not consistent with those at Site 47, then additional locations will be investigated as potential reference locations.

The sediment reference location will be selected from the freshwater sediment sampling locations used in the Background Soil Investigation Report. Care will be taken to ensure that the physical characteristics (i.e., similar grain size and amount of organic material) of the reference sediment closely resembles that of the site sediment. If a representative reference location is unavailable, a known area of minimal contamination in the vicinity of the site samples will be used as the reference (e.g., IS47SS18).

The reference soil samples will be analyzed for TAL metals, PAHs, TOC, pH, and grain size. The reference sediment sample will be analyzed for the same suite of parameters, with the exception of pH, which will be measured in situ.

Samples to be collected for the following analyses:

Summary of Samples to be Submitted to the Laboratory

Matrix	Laboratory Parameter	Samples	Field Duplicates	Field Blanks	Equipment Blanks	Matrix Spikes	Total Samples
Soil	TAL metals	12	2	1	2	1/1	19
	PAHs (SIM)	12	2	1	2	1/1	19
	TOC	12	2	—	—	—	14
	pH	12	2	—	—	—	14
	Grain size (sieve)	12	—	—	—	—	12
Sediment	TAL metals	3	—	—	1	1/1	6
	PAHs (SIM)	3	—	—	1	1/1	6
	TOC	3	—	—	—	—	3
	Grain size (sieve)	3	—	—	—	—	3
Surface Water	TAL metals (total and dissolved)	4	—	—	—	1/1	6
	DOC	2	—	—	—	—	2
	pH	2	—	—	—	—	2
	Hardness	2	—	—	—	—	2

Summary of Samples to be Submitted to the Laboratory

Matrix	Laboratory Parameter	Samples	Field Duplicates	Field Blanks	Equipment Blanks	Matrix Spikes	Total Samples
Tissue	TAL metals	10	—	—	—	1/1	12
Toxicity Testing							
Soil	Toxicity test	12	—	—	—	—	12
Sediment	Toxicity test	3	—	—	—	—	3

Notes: One field blank will be collected during the sampling event. An equipment blank will be collected for each sampling day and medium. Matrix spikes are two samples: one matrix spike and one matrix spike duplicate.

Analytical methods to be used are as follows:

Analytical Methods

Analysis	Methodology
TAL Metals	U.S. EPA CLP Inorganics SOW ILM04
PAHs	SW-846 8270 SIM PAH
TOC	Lloyd Kahn Method
pH	SW-846 Method 9045
DOC	SW-846 9060A
Grain Size	ASTM D-422 (sieve analysis, include graph, no hydrometer)
Surface Water Hardness	EPA Method 130.1
42-day Toxicity Test	ASTM E 1706-00 (ASTM, 2001a); EPA/R-99/064 (USEPA, 2000)
28-day Toxicity Test	ASTM E1676-97 (ASTM, 2001b); EPA/600/3-88/029 (USEPA, 1989)

All sample containers will be provided by the laboratory subcontractor in a clean and, if appropriate, pre-preserved state, as defined in the Master Plans for Installation Restoration Program Environmental Investigations (Tetra Tech NUS, 2004) (herein referred to as Master Plans). Laboratory-grade contaminant-free water will be provided by the laboratory subcontractor for equipment blanks. Pre-prepared trip blanks will be provided by the laboratory subcontractor. Analytical results will be delivered in both hard copy and electronic data packages using standard 28-day turnaround time.

5.2 Quality Assurance Project Plan

Quality assurance procedures are described in the *Master Quality Assurance Project Plan* (QAPP) of the Master Plans. Data will be collected to meet high-level DQOs. The data quality objectives for this project are presented in the Master QAPP, which describes the quality control protocols necessary to achieve the study objectives. Quality control (QC) samples will be used to verify the accuracy and precision of the chemical data generated during the investigation. When data are suspect because a QC sample is outside of a laboratory's established control limits, the data user will be notified through the laboratory report's case narrative and the data validator's report. No field QC samples will be collected for the laboratory toxicity tests. Analytical results will be validated by an independent data validator using U.S. Environmental Protection Agency Region III modifications to the

National Functional Guidelines, as described in the Addendum to Master Plans (CH2M HILL, 2000).

Field QC samples will be collected as follows for analytical samples:

Type of QC Sample	Frequency Collected
Field Duplicate	One per matrix for each group of up to 10 samples
Field Blank	One for the event
Equipment Blank	One every day if equipment is decontaminated for reuse
Matrix Spike/Matrix Spike Duplicate	One pair for each group of up to 20 samples per media sent to a single laboratory

5.2.1 Sample Identification System

Each sample will be designated by an alphanumeric code that identifies the site and matrix sampled and contains a sequential sample number. Site-specific procedures are elaborated below.

The following is a general guide for sample identification:

First Segment of Sample Number:	Second Segment of Sample Number:	Third Segment of Sample Number		
Naval Installation Abbreviation	Site Number	Sample Type	Sample Location	Additional Qualifiers (sample depth, date)
A	ANN	AA	NN	NNNN

Symbol Definition:

"A" = Alphabetic
"N" = Numeric

Site Abbreviation:

A = One letter abbreviation identifying the Naval Installation where the sample was collected (i.e., Indian Head = I)

Site Number:

ANN = One letter and two numbers identifying the site on the facility where the sample was collected (i.e., S47 = Site 47)

Sample Type:

TX = Toxicity Test Sample
SS = Surface Soil
SD = Sediment Sample
EB = Equipment Blank
FB = Field Blank

Sample Location:

MM = QC Samples—two-digit month of sampling event
NN = Primary Samples—two-digit number indicating sample location

Additional Qualifiers:

BDED = Sediment or Surface Soil Sam—two-digit begin depth and two-digit end depth rounded up to nearest foot (i.e., 2 ft to 2 ft 6 in. = 0203)

DDYY = QC Samples—two-digit day and two-digit year of sampling event

An example of this numbering approach is:

IS47SD040001 The 4th surface sediment sample collected at Site 47 from 0 ft to 1 ft bgs

An example of this numbering approach for QA/QC samples is:

IS47EB031502 Equipment blank collected at Site 47 on March 15, 2002

Field duplicates will be "blind duplicates," and thus labeled in the same manner as regular samples. Their locations and corresponding sample numbers will be recorded in the logbook.

5.2.2 Sample Packaging and Shipping

Samples will be tightly packed in a cooler with bubble wrap packaging material and ice as a preservative. The samples will be either picked up at the site by the analytical laboratory or shipped to the laboratory via overnight courier. The field team leader is responsible for completion of the following forms:

- Sample labels and Chain of Custody seals
- Chain of Custody forms
- Appropriate labels and forms required for shipment

Custody of the samples will be maintained and documented at all times. Chain-of-Custody will begin with the collection of the samples in the field and will continue through the analysis of the sample at the analytical laboratory.

5.3 Health and Safety

An addendum to CH2M HILL's health and safety plan for Site 47 will be prepared for this field effort. The field team will conduct all fieldwork in accordance with the plan and addendum and as well as NDWIH safety.

5.4 Investigation-Derived Waste Management

Small amounts of liquid investigation-derived waste (IDW) will be generated during decontamination of sampling equipment. Disposable sampling equipment will be used wherever possible to minimize the generation of decontamination rinse water. All IDW and

personal protective equipment used during the sampling will be disposed of per the *Master Field Sampling Plan* of the Master Plans.

5.5 Data Analysis

After the data are validated, the project chemist and risk assessors will determine whether the data are of sufficient quality to meet project DQOs and can be utilized in risk evaluations. After data validation, data analyses that will be conducted fall into two areas:

Comparison of biological response between site and reference toxicity tests. Statistical comparison will be conducted for growth and survival. The tests will determine whether organism performance is significantly different when exposed to soil or sediment collected from the site relative to the reference area. Statistical testing may also be conducted with control data. The reproduction data will likely not be analyzed statistically because these data are sometimes limited due to food availability in the site and/or reference media. Reproduction data will be evaluated as appropriate, dependent on the robustness of the data set obtained at the conclusion of the tests.

Existence of patterns in laboratory toxicity testing results with chemical burden and other chemical/physical characteristics of the sediments. Through multiple regressions or other appropriate statistical analyses, the data will be reviewed to determine whether there are relationships between biological response in the toxicity tests and the chemical content of the soil or sediment. Other factors that may be used in the analyses include carbon and grain size adjustments.

5.6 Project Reporting

The methods, results, analyses, and risk characterization will be presented in a Baseline Ecological Risk Assessment report. The report will also present an evaluation of the potential risk to ecological receptor populations at Site 47. If a risk exists, the spatial extent that should be considered for remedial action will be identified in the report for discussion by the NDWIH Installation Restoration Team.

SECTION 6

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