N00174.AR.000486
NSWC INDIAN HEAD
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Final

Work Plan for Baseline Ecological Risk Assessment Site 28

Naval District Washington, Indian Head
Indian Head, Maryland

Contract Task Order 0111

August 2005

Prepared for

Department of the Navy
Naval Facilities Engineering Command Washington

Under the

LANTDIV CLEAN II Program
Contract N62470-95-D-6007

Prepared by

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Abbreviations and Acronyms

BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BTAG	Biological Technical Assistance Group
CLEAN	Comprehensive Long-term Environmental Action Navy
COC	contaminant of concern
CSM	conceptual site model
CTO	Contract Task Order
DOC	dissolved organic carbon
DQO	data quality objective
ERA	ecological risk assessment
ERL	effects range low
ft	feet
FSP	Field Sampling Plan
GIS	geographic information system
HQ	hazard quotient
IDW	investigation-derived waste
IHIRT	Indian Head Installation Restoration Team
LC_{50}	lethal concentration 50 percent
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/L	micrograms per liter
NDWIH	Naval District Washington, Indian Head
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
ORP	oxidation-reduction potential
QAPP	Quality Assurance Project Plan
QC	quality control
RI	Remedial Investigation
RPM	Remedial Project Manager
SERA	Screening Ecological Risk Assessment
SQG	sediment quality guideline
SVOC	semivolatile organic compound

TAL	target analyte list
TCL	target compound list
TIE	toxicity identification evaluation
TOC	total organic carbon
UET	upper effects threshold
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

SECTION 1

Introduction

This Baseline Ecological Risk Assessment (BERA) Work Plan for Site 28, located at the Naval District Washington, Indian Head (NDWIH), Indian Head, Maryland, was prepared under Contract Task Order (CTO) 0111, Comprehensive Long-Term Environmental Action Navy (CLEAN), contract number N62470-95-D-6007.

1.1 Document Organization

This work plan is organized as follows: Section 1 presents the document and project organization; Section 2 presents a general description of the facility and the site, the site history, and a description of previous ecological risk assessment results for 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 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. Jeff Morris.

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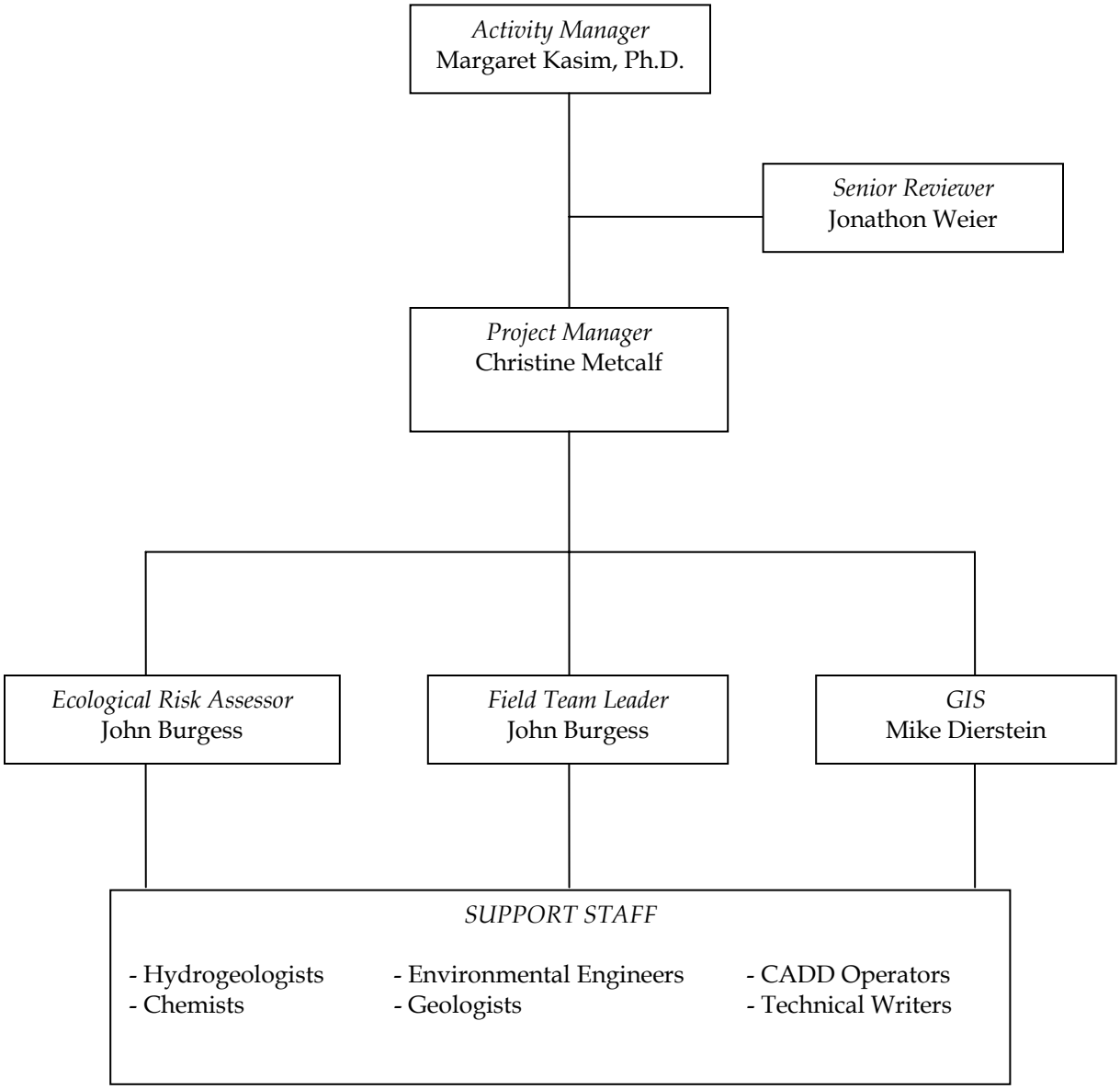
The CH2M HILL project organization is shown in Figure 1-1.

FIGURE 1-1
Project Organization Chart



SECTION 2

Site Background

Naval District Washington, Indian Head is located in northwestern Charles County, Maryland, approximately 25 miles southwest of Washington, District of Columbia. NDWIH is a Navy facility consisting of the main installation on Cornwallis Neck Peninsula and the Stump Neck Annex on Stump Neck Peninsula. The main installation is approximately 2,500 acres 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 (Figure 2-1). Included as part of the main installation are Marsh Island and Thoroughfare Island, which are located in Mattawoman Creek.

Site 28, also referred to as the "Original NOS Burning Ground," the "Slavins Dock Area," and the "Wildlife Area," is located on the main installation of NDWIH (Figure 2-1). The site encompasses the former site of a zinc recovery furnace, Well 14, and a shoreline burning cage (Figure 2-2).

During World War I, the U.S. Navy initiated a metal-recycling program, which was vital during World War II. In 1928, the zinc recovery furnace, designated Building 415, was erected. The last station map on which the building appears is dated October 31, 1952 (Dolph, 2001).

A small burning cage to the south of Well 14 was used to burn debris (e.g., wooden crates). The exact location of the former burning cage is unknown. The burning cage is shown outside of the existing perimeter fence on at least one historical map; however, burned debris, glass, and slaglike materials were observed inside the fence in an area adjacent to the mouth of Swale 4 (Figure 2-2).

The area where the zinc recovery furnace and the small burning cage were located is referred to as Zone A (Figure 2-2). Zone A comprises the area between the north and south fence lines, the area outside of the fence line to the north, and shoreline to the east, as shown on Figure 2-2.

The area referred to as the "Original Burning Ground" in the Initial Assessment Study (NEESA, 1983) and as the "Shoreline Burning Cage" by Dolph (2001) is included in Zone B. This area, outside the NDWIH fence line but within Navy property, is south of Zone A (Figure 2-2).

2.1 Environmental Setting

The 1.8-acre, eastward-sloping site includes a mixture of habitats. The northern portion of Zone A is comprised mostly of tall grass, with some areas of exposed substrate (i.e., debris, soil, and gravel). There are four swales in Zone A that discharge to Mattawoman Creek. Swales 2 and 3 connect with Swale 1, which conveys stormwater runoff into Mattawoman Creek (Figure 2-2). The discharge area for Swale 1 supports a small emergent wetland habitat dominated by obligate wetland vegetation. Flow in these swales is intermittent,

responding to seasonal fluctuations, and appears to contain groundwater discharging to the ground surface as springs.

Swale 4, in the southern portion of Zone A, collects water via a culvert that runs from west of the dirt road at Site 28 under the road. This drainage also receives runoff from the site. The results of the Remedial Investigation (RI) suggest that the major source of water in Swale 4 is likely groundwater (CH2M HILL, 2005). The presence of water and obligate wetlands vegetation during dry periods suggest that Swale 4 flows perennially.

The southern portion of Zone A and most of Zone B is mixed hardwood forest. The tree cover in this area is primarily deciduous (e.g., oak, maple, and sweet gum), with a few conifer species. There are several areas (e.g., adjacent to the southern fence line) where a shrubby understory is present. There are also several wetland areas in the forested portion of the site.

The shoreline between Site 28 and Mattawoman Creek is tidally influenced, varies from a sand/gravel to muddy composition, and supports few herbaceous plant species. The littoral zone adjacent to the site is composed of a predominantly sand and gravel substrate along the central portion of the site, in contrast to the fine silty mud substrate immediately upstream and downstream of the site. The abundance of sand and gravel adjacent to the site may be an indication of historical erosion of soils from the site to Mattawoman Creek.

Site 28 contains a number of habitats and, therefore, is likely to support a number of species including mammals, songbirds, raptors, reptiles, and amphibians. The portion of Site 28 that is directly adjacent to Mattawoman Creek supports a number of aquatic bird species. A survey of rare, threatened, and endangered species was conducted by the Maryland Natural Heritage Program in 1991 and 1992 (MDNR, 1992). The survey focused on areas with a high potential for supporting rare, threatened, and endangered species. Of the listed species, the bald eagle (*Haliaeetus leucocephalus*) is the only known federally listed threatened species identified on NDWIH. The remainder of the species listed includes five state-listed endangered plants, two state-listed threatened plants, one state-listed endangered invertebrate, and 18 species of regional concern.

2.2 Previous Ecological Risk Assessment Activities

A screening ecological risk assessment (SERA) was completed for Site 28 as part of the RI for the site (CH2M HILL, 2005). This section summarizes the data used for the SERA, as well as the risk characterization and conclusions.

2.2.1 Data Collected for the SERA

This subsection summarizes, by medium, the data collected for the RI and used in the SERA for Site 28.

Surface Soil

In 2003, 35 surface soil samples were collected at a depth interval of 0 to 1 ft (Figure 2-3). These samples were analyzed for Target Analyte List (TAL) metals, Target Compound List (TCL) semivolatile organic compounds (SVOCs), explosives, TCL volatile organic compounds (VOCs), pH, total organic carbon (TOC), and grain size.

On-Site Sediment and Surface Water

Three colocated sediment and surface water samples were collected from within the Site 28 boundary: one from the confluence of Swales 1, 2, and 3, and two from Swale 4 (Figure 2-4). Sediment samples were analyzed for TAL metals, TCL SVOCs, explosives, TCL VOCs, pH, TOC, and grain size. Surface water samples were analyzed for total and dissolved TAL metals, TCL SVOCs, explosives, TCL VOCs, pH, TOC, and dissolved organic carbon (DOC).

Mattawoman Creek Sediment

Sediment samples were collected from 15 locations in Mattawoman Creek adjacent to Site 28. Five sampling locations were located along the immediate Site 28 shoreline, five sampling locations were located in the channel, and five sampling locations were located in the littoral zone (shallow vegetated zone) along the depositional bar across the creek from Site 28 (Figure 2-4).

Sediment samples were collected from two depth intervals (0–6 inches and 6–12 inches). The surface sediment samples (0–6 inches) were collected to support the ecological risk assessment (ERA). The subsurface sediment samples (6–12 inches) were collected to aid in determining the nature and extent and potential off-site migration of chemicals into Mattawoman Creek, and were not included in the ERA. All samples were analyzed for TAL metals. At three locations—one from each sampling area (i.e., shoreline, channel, and depositional bar)—the surface and subsurface samples were also analyzed for TCL SVOCs, explosives, and TOC.

2.2.2 Results of Step 3A of the BERA

The results of the SERA suggested that potentially unacceptable ecological risks exist at Site 28. Therefore, the initial step of a BERA, Step 3, was completed and included with the SERA in the RI Report. 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. This step is conducted to assist with the identification of risk drivers (i.e., chemicals that may pose the greatest risk). The results of Step 3A of the BERA are presented in the following subsections, by medium.

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.

Surface Soil

Several metals were identified in Step 3A of the BERA as potential risk-driving contaminants of concern (COCs). Thirteen metals exceeded screening values based on detected mean concentrations (aluminum, antimony, beryllium, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, vanadium and zinc). Concentrations of these metals were compared to concentrations in NDWIH background samples collected for the Background Soil Investigation Report for Indian Head and Stump Neck Annex (Tetra Tech NUS, 2002a). Table 2-1 compares the concentrations of the metals for which background surface soil concentrations were available. Antimony was undetected in surface soil samples.

TABLE 2-1
Comparison of Concentrations of Surface Soil COCs to Background Surface Soil Concentrations
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

Chemical	Average Site Surface Soil Concentration (mg/kg)	Average Background Surface Soil Concentration (mg/kg)	Ratio (Site/Background)
Aluminum	5,809	7,540	0.8
Beryllium	0.22	0.44	0.5
Cadmium	15.7	0.4	**39.3**
Chromium	19.3	13.6	1.4
Copper	119	6.7	**17.8**
Iron	19,163	13,000	1.5
Lead	794	18.7	**42.5**
Mercury	0.55	0.06	**9.2**
Nickel	10.6	5.4	**2**
Silver	1.72	0.6	**2.9**
Vanadium	23.5	23.3	1.0
Zinc	9,594	20.2	**475**

Bold text indicates site/background ratio greater than 1.5.

As shown in Table 2-1, the average site concentrations of aluminum and beryllium are below background levels. The site/background ratios of chromium, iron, and vanadium are all less than or equal to 1.5. While it cannot be concluded that these metals pose no risk to soil invertebrates or plants at Site 28, the results of the background comparison provide evidence to suggest that site-related risk may be overestimated. As such, aluminum, beryllium, chromium, iron, and vanadium were not considered potential risk drivers for surface soil. Cadmium, copper, lead, mercury, nickel, silver, and zinc, as well as antimony, were identified as potential risk-driving COCs in surface soil.

On-Site Sediment (Swales and Shoreline)

The sediment samples included in the on-site sediment screening included the three surface sediment samples collected from the on-site swales (IS28SD01-0503 through IS28SD03-0503) and the five surface sediment samples (IS28SD01 through IS28SD05) collected along the shoreline of Mattawoman Creek (Figure 2-4).

Several metals were identified in Step 3A of the BERA as posing potential risk to benthic invertebrates and plants in on-site sediments. Six metals exceeded screening values based on detected mean concentrations (arsenic, cadmium, chromium, copper, lead, and zinc) and five metals (barium, beryllium, cobalt, selenium, and vanadium) were detected but had no screening values. Concentrations of the eleven metal COCs in on-site sediment were compared to concentrations detected in NDWIH background sediment samples collected

from freshwater streams believed not to have been impacted by facility operations (i.e., four locations on Stump Neck Annex, three on NDWIH, two from a nearby State Park, and one from a nearby State Forest) (Tetra Tech NUS, 2002a). Table 2-2 compares the concentrations of the metals for which background sediment concentrations were available.

TABLE 2-2
Comparison of Concentrations of On-Site Sediment COCs to Background Sediment Concentrations
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

Chemical	Average Sediment Site Concentration (mg/kg)	Average Sediment Background Concentration (mg/kg)	Ratio (Site/Background)
Arsenic	49.2	3.3	**14.9**
Barium	53.7	42.0	1.3
Beryllium	0.19	0.52	0.4
Cadmium	9.44	0.35	**27**
Chromium	10.7	11.6	0.9
Cobalt	5.13	5.97	0.9
Copper	55.8	9.5	**5.9**
Lead	372	23.1	**16.1**
Selenium	0.72	0.93	0.8
Vanadium	13.7	18.6	0.7
Zinc	5,762	41.2	**139.9**

Bold text indicates site/background ratio greater than 1.5.

As shown in Table 2-2, the average site concentrations of beryllium, chromium, cobalt, selenium, and vanadium were less than the average background concentrations for these metals. The site/background ratio of barium was 1.3. Because these COCs were lower than or similar to background sediment concentrations, it is unlikely that their concentrations are site related. Thus, barium, beryllium, chromium, cobalt, selenium, and vanadium are not considered risk drivers. Arsenic, cadmium, copper, lead, and zinc were identified as potential risk-driving COCs in on-site sediment.

Surface Water

Several metals were identified in Step 3A of the BERA as posing potential risk to water column receptors at Site 28. Five detected metals had mean-based hazard quotients (HQs) greater than 1 for total metals (cadmium, copper, iron, lead, and zinc). However, only cadmium and zinc were detected in the filtered samples, which were considered appropriate for the screening comparison because most of the ecological screening values are derived from toxicity studies evaluating the dissolved form of the metals. The dissolved form is more mobile and bioavailable and would therefore pose the higher potential risk to ecological receptors. Both cadmium and zinc were detected at concentrations exceeding

their respective screening values; thus, cadmium and zinc are considered potential risk-driving COCs for surface water.

Mattawoman Creek Sediment

The sediment samples for the Mattawoman Creek sediment screening included the five surface sediment samples collected in the channel, and the five collected from the littoral zone of the depositional bar across from Site 28 (Figure 2-4).

Several metals were identified in Step 3A of the BERA as posing potential risk to benthic invertebrates and plants in Mattawoman Creek sediments. Chromium and silver exceeded screening values based on detected mean concentrations, and five metals were detected (i.e., barium, beryllium, cobalt, selenium, and vanadium) for which screening values were not available.

Chromium concentrations in the channel samples (IS28SD06 through IS28SD10) were all below the reported Mattawoman Creek background concentration for chromium of 21.3 mg/kg (Area 6 of the Mattawoman Creek Study; Tetra Tech NUS, 2002b) and 44 mg/kg (mean concentration of six samples collected at the mouth of Mattawoman Creek; Tetra Tech NUS, 2002a).

In contrast, the samples collected along the depositional bar (IS28SD11 through IS28SD15) contained chromium concentrations ranging from 19.2 to 27.8 mg/kg, which are consistent with or slightly greater than the background concentration of 21.3 mg/kg reported in the Mattawoman Creek Study (Tetra Tech NUS, 2002b), but below the background concentration of 44 mg/kg for freshwater sediment reported in the Background Study (Tetra Tech NUS, 2002a). Additionally, these concentrations are less than the National Oceanic and Atmospheric Administration (NOAA) freshwater sediment screening value for chromium of 37.3 mg/kg (Buchmann, 1999).

The chromium concentrations in the samples collected along the Site 28 shoreline (IS28SD01 through IS28SD05) ranged from 3.4 to 16.7 mg/kg. The fact that chromium concentrations in the channel and depositional bar sediments are consistent with background, and chromium concentrations in sediment along the immediate shoreline of the site are lower than those measured in the channel and depositional bar sediments, suggests that Site 28 is likely not the source of chromium measured in the sediment along the depositional bar. Thus, chromium was not considered a site-related COC for the Mattawoman Creek sediments.

Silver was detected in 9 of the 10 Mattawoman Creek sediment samples. The maximum concentration was 4 mg/kg and the average was 2.07 mg/kg. Silver was detected above background levels in sediments in the channel and in the area of the depositional bar; however, of the eight on-site sediment samples, six contained no silver (Figure 2-4). This suggests that silver measured in the channel and bar sediments may not have been transported from Site 28; however, because it is present at concentrations above background levels, silver was retained as a potential risk-driving COC for the Mattawoman Creek sediments.

On-Site Food Web Exposures

A potential risk from COCs in the on-site soils and sediments (swales and immediate shoreline) was identified for all the upper-trophic-level assessment endpoints evaluated in

the ERA. Zinc was found to be the primary risk driver. Although upper-trophic-level receptors are likely to forage over a larger area than that represented by the site alone, this limited exposure evaluation was used to conservatively estimate potential risk from on-site soil and sediment. The estimated dose of the following metals resulted in No Observed Adverse Effects Level (NOAEL)-based HQs exceeding 1 for the receptors listed:

- Arsenic—shrew, vole, muskrat
- Cadmium—shrew, vole, fox, robin, dove, owl, swallow
- Lead—shrew, robin, dove, owl, heron, mallard, swallow
- Mercury—shrew, heron
- Selenium—shrew, vole
- Zinc—all receptors

Based on the refined risk calculations, arsenic, cadmium, lead, mercury, selenium, and zinc are potential risk-driving COCs for upper-trophic-level receptors utilizing the habitats at Site 28.

Mattawoman Creek Foodweb Exposure

A similar analysis was performed to evaluate upper-trophic-level receptor exposure to sediments in Mattawoman Creek adjacent to the site (i.e., the channel and depositional bar samples, IS28SD06 through IS28SD15), but excluding the immediate shoreline area. A potential risk to piscivorous birds (i.e., fish-eating birds represented by great blue heron) was identified for mercury (NOAEL-based HQ of 2.42). Therefore, the data suggest that the potential risk to upper-trophic-level receptors from site-related sediment COCs is limited to the sediments in the swales and along the immediate shoreline of the site. However, it is likely that the potential risk is not related to Site 28 because mercury was detected in only 1 of the 10 surface sediment samples away from the immediate shoreline (IS28SD11), and only in 1 of the 5 surface sediment samples along the immediate shoreline (IS28SD04). The concentrations detected at these locations were 0.44 and 0.37 mg/kg, respectively. These concentrations fall within the range of background mercury levels (0.17 to 0.74 mg/kg) reported for Mattawoman Creek (Tetra Tech NUS, 2002b).

2.2.3 Spatial Distribution of COCs in Surface Soil

Based on a review of the spatial distribution of COCs in surface soil, the highest concentrations of metals were measured in samples collected in the center of Zone A (the probable location of the zinc recovery furnace). Of the eight soil COCs, five (antimony, cadmium, copper, lead, and nickel) had maximum concentrations detected in the surface soil sample from Station IS28SO19 (Figure 2-3). The maximum mercury concentration was measured in the surface soil sample from Station IS28SO15, the maximum silver concentration in the surface soil sample from Station IS28SO10, and the maximum zinc concentration in the surface soil sample from Station IS28SO08 (Figure 2-3). Relatively high concentrations of all of the COCs were measured in samples collected adjacent to the swales.

2.2.4 Spatial Distribution of COCs in Site Sediment

The maximum concentration of each COC in on-site sediment was measured in sample IS28SD02-0503 (Figure 2-4). This sample location was in the upgradient portion of Swale 4. The second highest COC concentrations measured were in samples IS28SD03-0503 (arsenic

and cadmium) and IS28SD05 (copper, lead, and zinc). Relatively low COC concentrations were detected in IS28SD01-0503 just downgradient in Swale 4. Although COCs were present in Swale 4, the high concentrations detected in Swales 1–3, and at IS28SD05 (at the mouth of Swale 1) suggest that there is potentially more migration of COCs offsite via Swale 1 than Swale 4. For most COCs, concentrations at IS28SD01 and IS28SD02 are much lower than at IS28SD05, IS28SD04, or IS28SD03, (particularly for zinc), suggesting that site-related contamination is most notable adjacent to Zone A where the swales discharge to Mattawoman Creek (Figure 2-4).

2.2.5 Spatial Distribution of COCs in Surface Water

The maximum concentrations of cadmium and zinc were measured in surface water sample location IS28SW02-0503 (collected from the same location as sediment sample IS28SD02-0503, shown in Figure 2-4). This surface water sampling location (in the upgradient portion of Swale 4) corresponds with the location of maximum concentration for each inorganic COC in sediment (IS28SD02-0503).

2.3 Environmental Media and COCs for the BERA

This work plan is designed to assess potential ecological risk from contaminants in the sediment along the immediate shoreline of Site 28 and in the sediments of Mattawoman Creek. Only one COC (silver) was identified for sediment away from the immediate shoreline. Surface soil and the on-site swales are not included in the work plan because a soil removal action will be conducted to mitigate human health risk from lead in surface/subsurface soil and to mitigate ecological risk from various COCs in the surface soil and sediment in the swales. Further evaluation of the groundwater to surface water pathway was initially included in this work plan, but was removed following discussion at the June 30, 2005, Partnering Meeting. A consensus was reached to defer additional investigation of ecological risk from contaminants in surface water until after the soil removal action is completed. It was agreed that further evaluation of surface water would be conducted as part of a post-removal monitoring effort, rather than as part of the BERA investigation, because this approach would provide a post-source control assessment of ecological risk. A human-health-driven removal action was initially proposed to remove lead-contaminated soil in areas identified by the human health risk analysis as discrete elevated lead locations. The current average site-wide lead concentration is below the 400 milligrams per kilogram (mg/kg) action level (for unrestricted use); however, additional risk assessment was performed in response to EPA's comment on the Draft Final RI Report. The current proposed action for human-health-associated risk is to remove soil with lead concentrations greater than 1,000 mg/kg, excavating to a depth of 1 to 5 feet below ground surface (bgs) or to the water table, whichever is shallower.

The proposed removal area was subsequently expanded to include the areas of the site that pose potential risks to ecological receptors (Figure 2-5). Preliminary remedial goals (PRGs) for surface soil were developed for the site based on the results of bioassays conducted at Site 47, NDWIH (CH2M HILL, 2005). The expanded soil removal would allow surface soil and sediment in the swales to be removed from consideration in the BERA for the site, which would subsequently focus on the sediments in Mattawoman Creek. This approach was presented to the Indian Head Installation Restoration Team (IHIRT) at the March 30,

2005, Partnering Meeting. The consensus of the team was to proceed with this approach pending United States Environmental Protection Agency (USEPA) consultation with the Region 3 Biological Technical Assistance Group (BTAG) to confirm the acceptability of the approach. EPA and BTAG agreed with the approach, pending an analysis showing that Site 47 soil is comparable to Site 28 soils and that the distribution of COCs above the PRGs demonstrates that the removal action will be adequately protective of ecological receptors. Consequently, this work plan is designed to assess potential ecological risk from chemicals in the sediments of Mattawoman Creek adjacent to the site.

2.3.1 Reevaluation of Shoreline Sediment (Not Including Sediment in Swales)

The shoreline sediments were reevaluated under the proposed soil/sediment removal scenario, in which the swales will be excavated and back-filled with clean soil. The results of this reevaluation indicate no change in the risk-driving COCs for sediment (Table 2-3).

TABLE 2-3
Re-evaluation of Shoreline Sediment (Not Including Sediment in Swales)
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

	Average Sediment Site Concentration			
Chemical	**Including Swales (mg/kg)**	**Shoreline Only (mg/kg)**	**Screening Value**	**Shoreline Hazard Quotient**
Arsenic	49.2	15.8	8.2	2
Cadmium	9.44	6.2	1.2	5
Copper	55.8	45.9	34	1
Lead	372	326	46.7	7
Zinc	5,762	4,736	150	32

The shoreline sediments were also reevaluated to determine if the risk-driving COCs for semiaquatic upper-trophic-level receptors would change under the proposed sediment removal action. The results of this reevaluation showed that the removal will result in a significant risk reduction. Table 2-4 shows the NOAEL and lowest observed adverse effect level (LOAEL) hazard quotients for semiaquatic upper-trophic receptors including the shoreline sediment and swale sediments. Table 2-5 shows the risk hazard quotients for aquatic receptors based on the shoreline sediments alone. The removal of sediment from the swales will adequately address the potential risk from arsenic and cadmium to semiaquatic upper-trophic-level receptors (Table 2-5). However, a potential risk would still exist from lead, mercury, and zinc, although the primary risk driver is zinc (Table 2-5).

The potential risk to piscivorous birds from mercury may not be site related because mercury was detected in only in 1 of the 5 surface sediment samples along the immediate shoreline (IS28SD04) and in only 1 of the 10 surface sediment samples away from the immediate shoreline (IS28SD11). The concentrations detected at these locations were 0.37 and 0.44 mg/kg, respectively. These concentrations are within the range of background levels (0.17 to 0.74 mg/kg) reported for Mattawoman Creek (Tetra Tech NUS, 2002b).

Therefore, mercury may not be a site-related hazard, but will be evaluated along with lead and zinc.

TABLE 2-4
Hazard Quotients for Food Web Exposure of Semiaquatic Receptors (Including Swale Sediments)
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

	Mink		Muskrat		Great Blue Heron		Mallard		Tree Swallow	
Chemical	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Arsenic	0.26	0.05	2.33	0.47	0.24	0.09	0.09	0.04	0.60	0.20
Cadmium	0.35	0.07	0.96	0.10	0.41	0.03	0.47	0.03	1.92	0.14
Chromium	<0.01	<0.01	0.03	<0.01	0.08	0.02	0.06	0.01	0.15	0.03
Copper	0.05	0.04	0.02	0.01	0.03	0.02	0.03	0.02	0.09	0.07
Lead	0.19	0.02	0.57	0.06	1.45	0.29	2.41	0.24	2.04	0.41
Mercury	0.10	0.06	0.23	0.05	3.08	1.03	0.22	0.07	0.04	0.02
Nickel	0.03	0.01	0.02	<0.01	0.03	0.02	<0.01	<0.01	0.02	0.02
Selenium	0.27	0.16	0.62	0.38	0.10	0.02	0.21	0.10	0.57	0.17
Silver	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.02
Zinc	6.68	1.34	2.99	1.49	21.67	2.40	23.63	2.62	81.13	8.98

Note: shaded cells indicate HQ>1.

TABLE 2-5
Hazard Quotients for Food Web Exposure of Semiaquatic Receptors (Shoreline Sediments Only)
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

	Mink		Muskrat		Great Blue Heron		Mallard		Tree Swallow	
Chemical	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Arsenic	0.06	0.01	0.41	0.08	0.07	0.03	0.02	<0.01	0.13	0.04
Cadmium	0.05	0.01	0.18	0.02	0.12	<0.01	0.13	<0.01	0.13	<0.01
Chromium	<0.01	<0.01	0.02	<0.01	0.07	0.01	0.05	<0.01	0.09	0.02
Copper	0.02	0.01	<0.01	<0.01	0.02	0.01	0.01	<0.01	0.03	0.02
Lead	0.10	<0.01	0.27	0.03	1.05	0.21	1.17	0.12	0.23	0.05
Mercury	0.07	0.04	0.06	0.01	2.20	0.73	0.09	0.03	<0.01	<0.01
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Silver	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	1.46	0.29	0.63	0.32	8.47	0.94	7.89	0.87	9.75	1.08

Note: shaded cells indicate HQ>1.

2.3.2 Summary of Risk-Driving COCs

Potential ecological receptors and associated risk-driving COCs are presented in Table 2-6.

TABLE 2-6
Potential Risk-Driving COCs by Ecological Receptor Group
Work Plan for Baseline Ecological Risk Assessment, Site 28, NDWIH, Indian Head, Maryland

COC	Benthic Invertebrates and Aquatic Plants	Water Column Receptors[2]	Semiaquatic Upper-Trophic-Level Receptors
Arsenic	x		
Cadmium	x	x	
Copper	x		
Lead	x		x
Mercury			x
Silver	x[1]		
Zinc	x	x	x

[1]Mattawoman Creek sediment only (not a COC for the immediate shoreline sediment).

[2]Potential risk to water column receptors will be evaluated after the soil/sediment removal is completed (as described in Section 2.3), thus no surface water data collection is proposed in this work plan.

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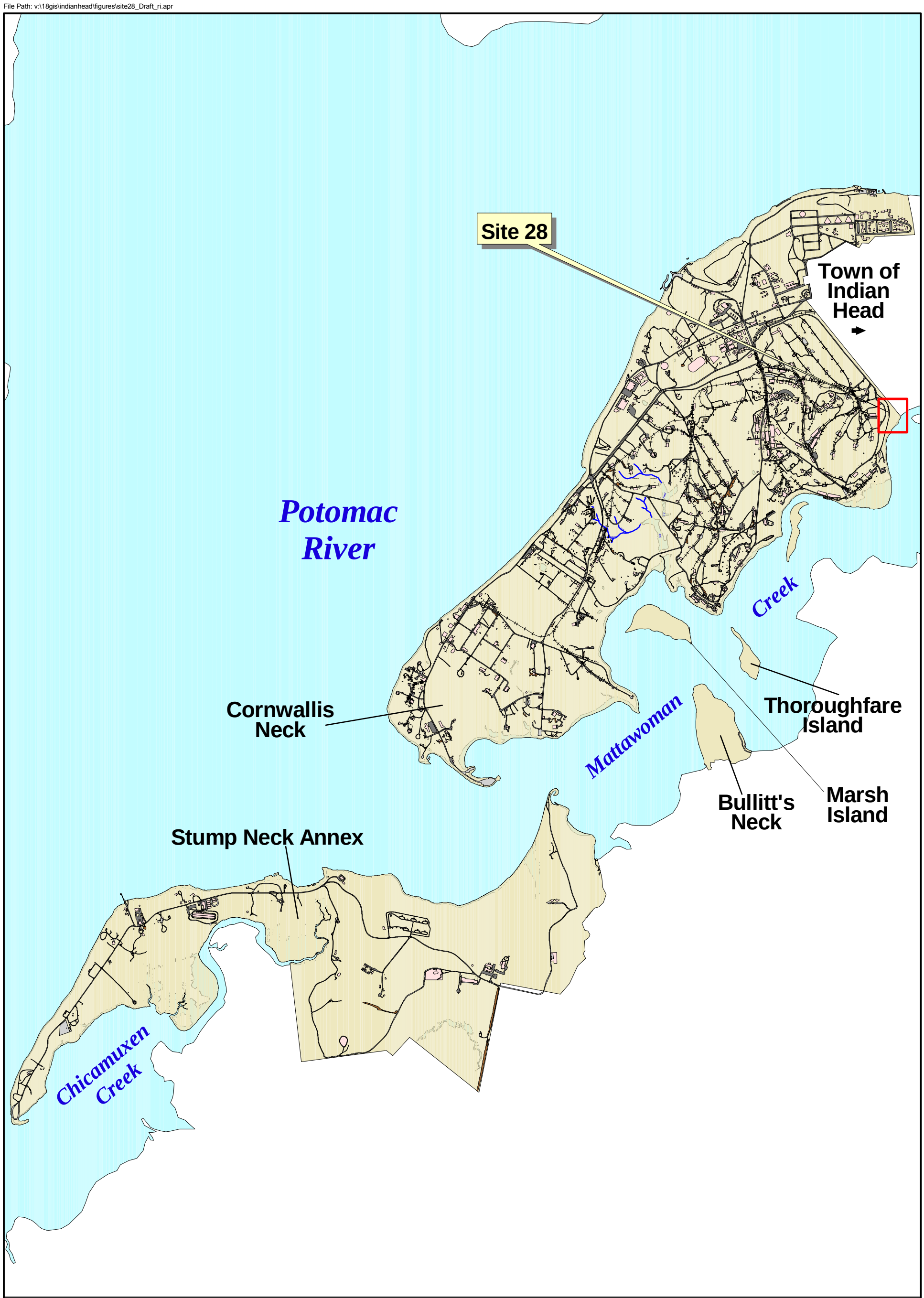

LEGEND

- IR Site Boundary
- Perennial Swale
- Intermittent Swale
- Railroads
- Buildings
- Asphalt Road
- Dirt Road
- Gravel Road

N

0 2500 5000 Feet

Figure 2-1
Base Map
Site 28 BERA Work Plan
NDWIH, Indian Head, Maryland

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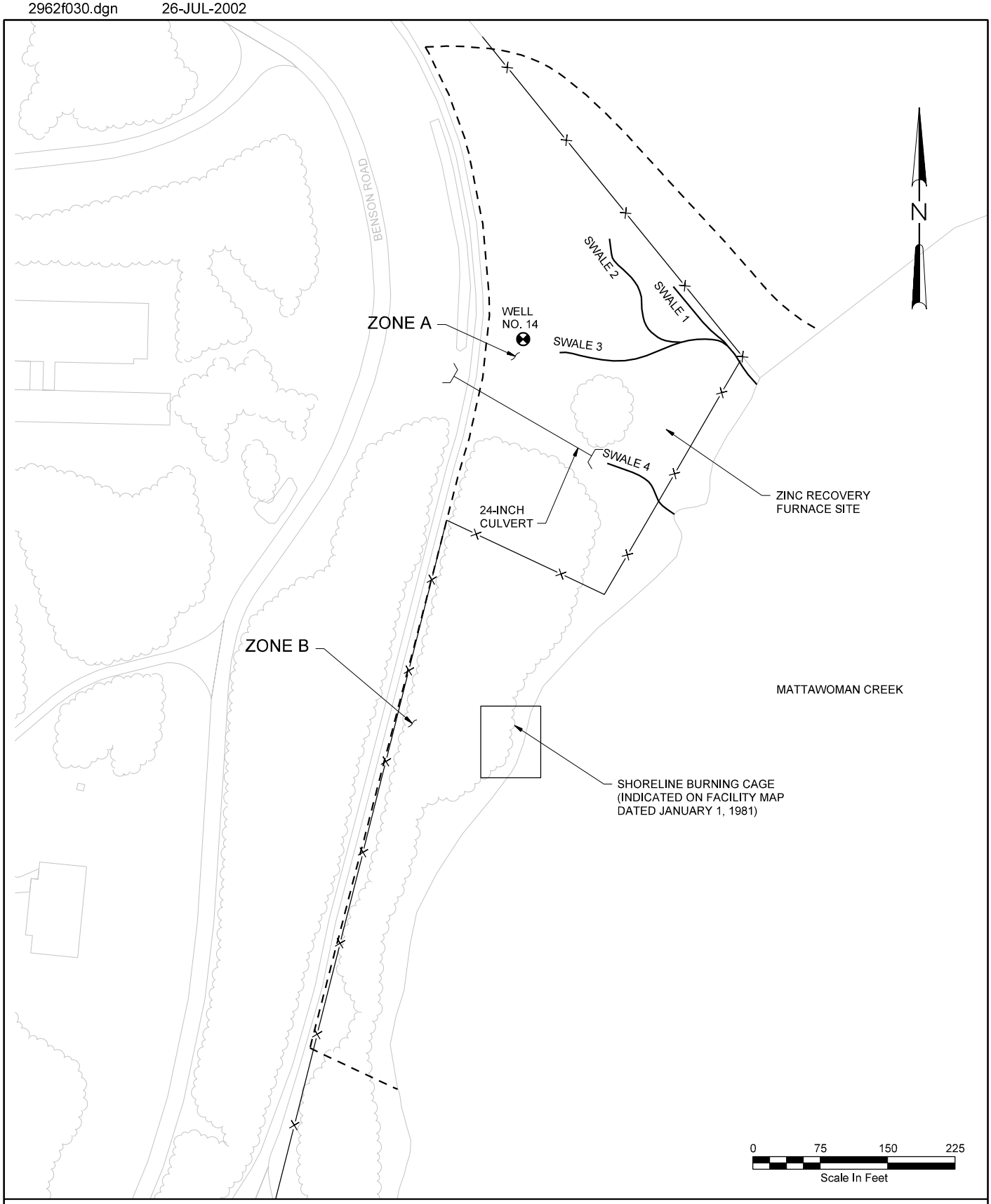

LEGEND

FENCE LINE

APPROXIMATE SITE BOUNDARY FOR RI

FIGURE 1-3
SITE 28
SITE 28 RI REPORT
NDWIH
INDIAN HEAD, MARYLAND

NOTE: SWALE LOCATIONS ARE APPROXIMATE.

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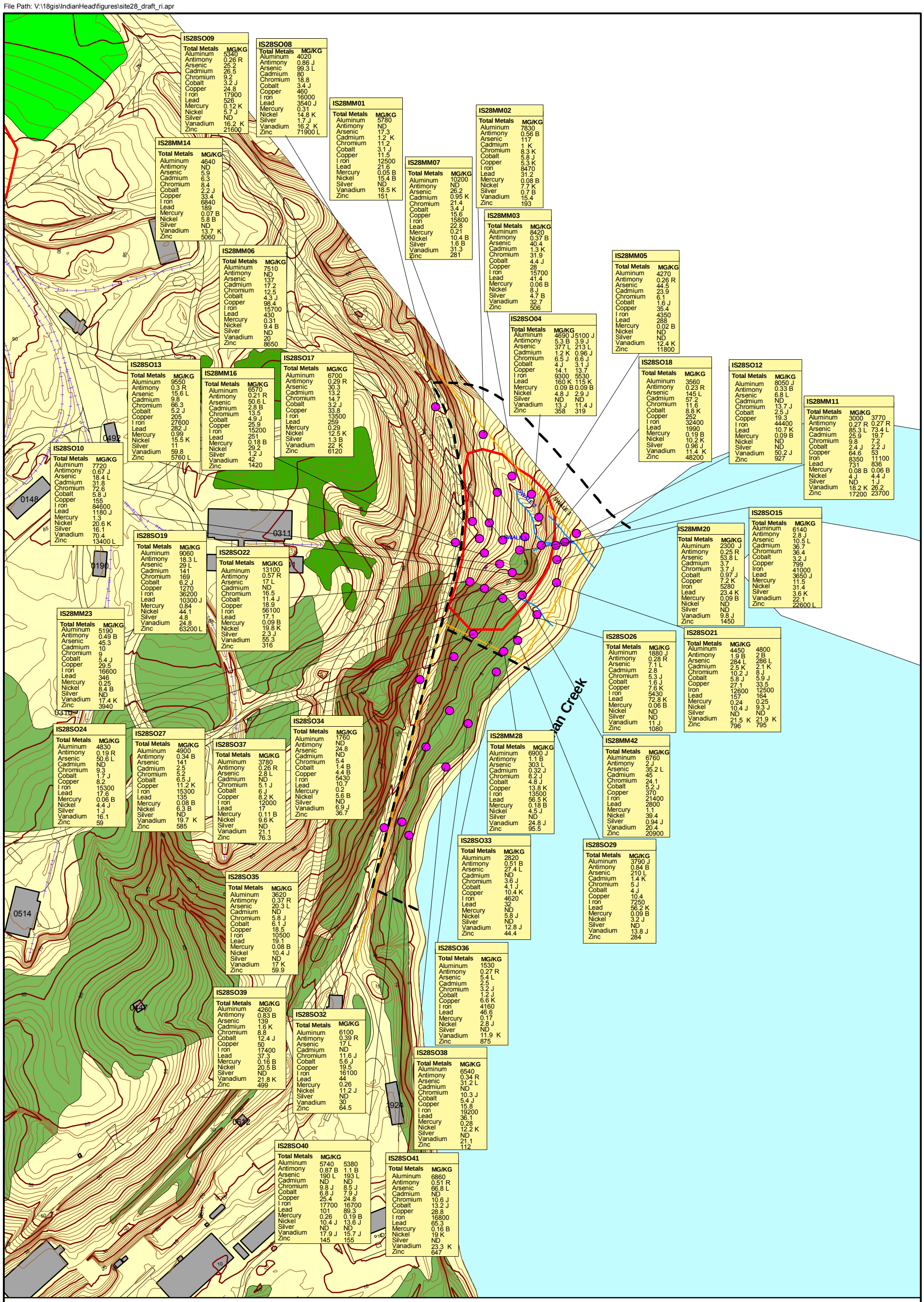

LEGEND

Sample locations are labeled with the Station ID

- Surface Soil Sample Location
- Zone Boundary
- Fence Line
- IR Site
- Five foot Contours
- One Foot Contours
- Buildings
- Railroads
- Roads

N

0 100 200 300 400 Feet

Figure 2-3
Selected Total Metals in Surface Soil
Site 28 BERA Work Plan
NDWIH Indian Head, Maryland

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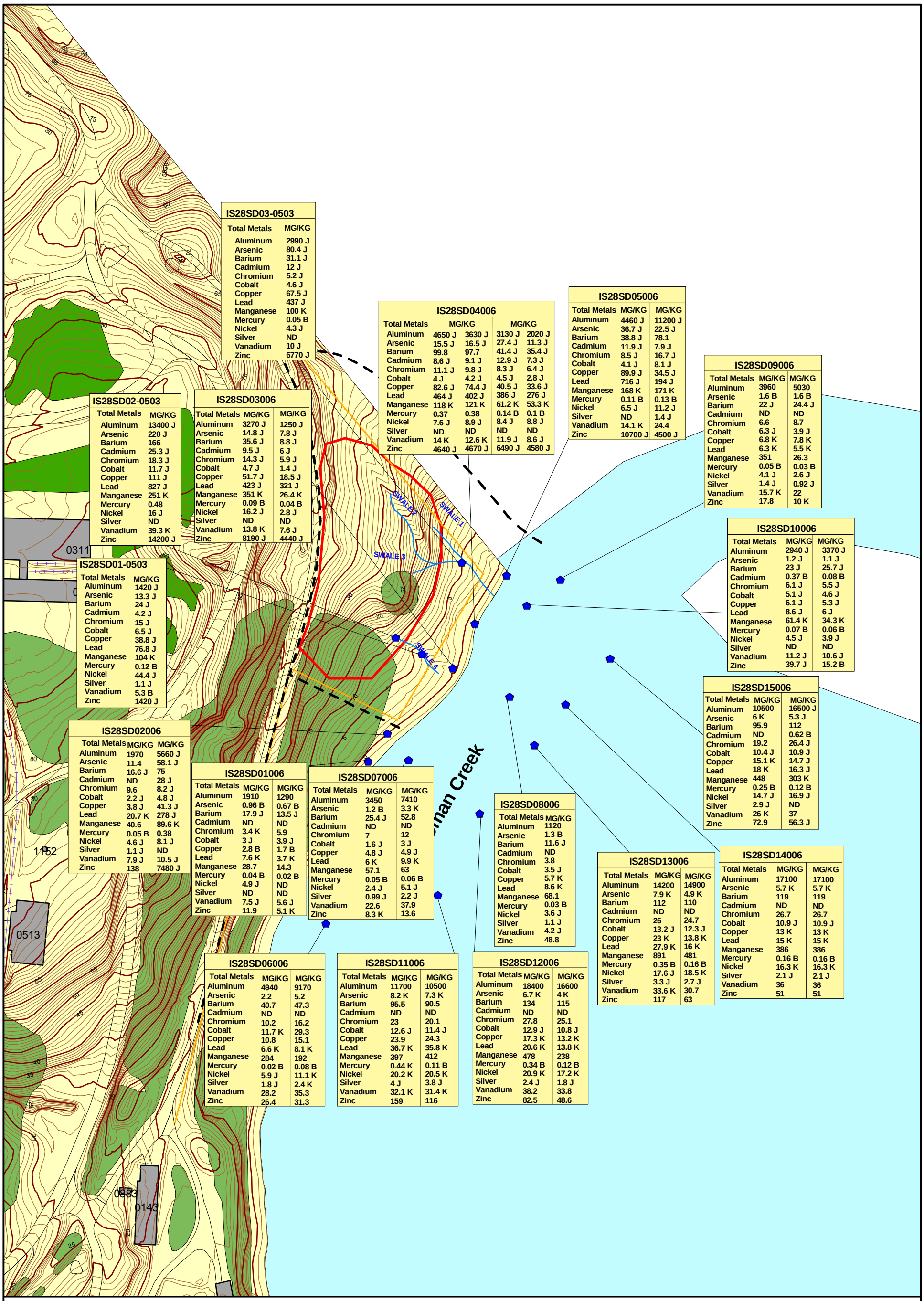


LEGEND

Sample locations are labeled with the Sample ID

- Mattawoman Creek Sediment Sample Location
- Zone Boundary
- Fence Line
- IR Site
- Five foot Contours
- One Foot Contours
- Buildings
- Railroads
- Roads

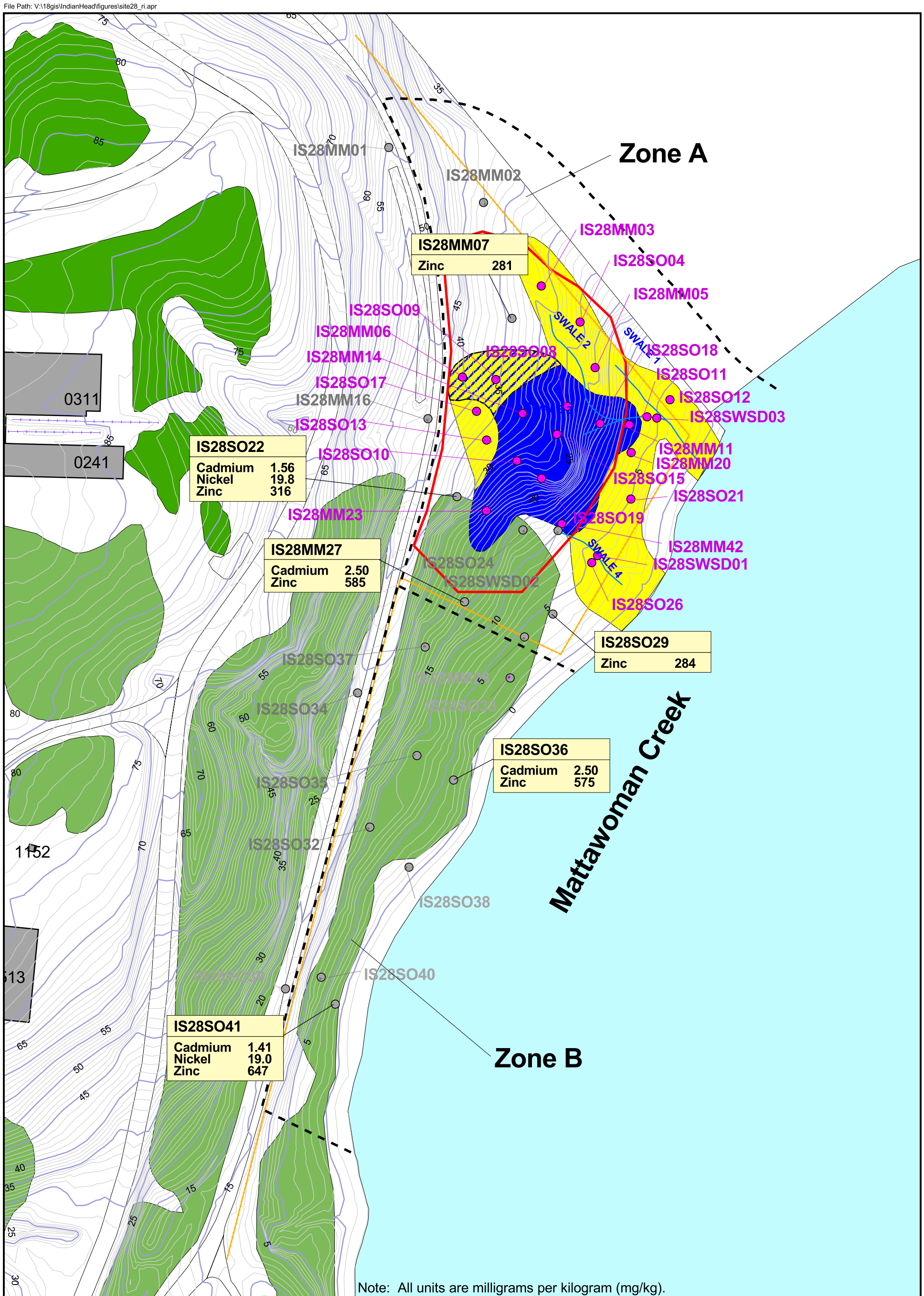
N

0 75 150 225 300 Feet

Figure 2-4
Selected Total Metals in Sediment
Site 28 BERA Work Plan
NDWIH Indian Head, Maryland

CH2MHILL

File Path: V:\18gis\IndianHead\figures\site28_ri.apr



LEGEND

- Sample Stations Included in Potential Soil Removal Area
- Sample Stations Not Included in Potential Soil Removal Area
- Soil Removal Based on Potential Ecological Risk
- Area of Limited Human Health Risk; Soil Removal Based on Ecological Risk
- Soil Removal Based on Potential Human Health Risk
- Zone Boundary
- Fence Line
- IR Site
- Buildings
- Railroads
- Roads
- Five foot Contours
- One Foot Contours

N

50 0 50 100 150 Feet

Figure 2-5
Distribution of COCs that Exceed PRGs
Outside the Removal Area
Site 28
NDWIH Indian Head, Maryland

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SECTION 3

BERA Problem Formulation

The BERA 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

Based on the Step 3A results, COCs pose a potential risk to the benthic invertebrates or aquatic plants, water column receptors, and semiaquatic upper-trophic-level receptors. The risk-driving COCs for benthic invertebrates or plants along the Site 28 shoreline are arsenic, cadmium, copper, lead, and zinc. The risk-driving COCs for surface water are cadmium and zinc. Additionally, lead, mercury, and zinc in shoreline sediment may pose a risk to upper-trophic-level receptors. Silver may pose a risk to benthic invertebrate and aquatic plant communities in Mattawoman Creek. Ecotoxicity profiles for each of the COCs are provided in the following subsections.

3.1.1 Arsenic

Arsenic occurs as two forms in environmental media: arsenic (III), usually the most toxic, and arsenic (V) (USEPA, 1985). The presence of arsenic in these forms is dependent on environmental conditions such as pH, organic content, amount of suspended solids, and sediment chemistry. Arsenic is readily adsorbed onto sediments containing abundant organic matter. The majority of the toxicity information available for arsenic is based on aqueous exposure studies. Therefore, little information is available on toxicity from sediment-associated arsenic.

Acute toxicity of arsenic (III) to six invertebrate species ranged from 0.812 mg/L for a water flea (USEPA, 1985) to 97.0 mg/L for a midge (Holcombe et al., 1983). Acute toxicity of arsenic (V) ranged from 0.69 mg/L for the alga *Selenastrum capricornutum* (USEPA, 1985) to 49.6 mg/L for *Daphnia pulex* (Passino and Novak, 1984). Three chronic toxicity values were calculated for arsenic (III) ranging from 0.914 mg/L to 3.026 mg/L for *Daphnia magna* and fathead minnow, *Pimephales promelas*, respectively (USEPA, 1985). The only chronic test that could be used to calculate a chronic value for arsenic (V) used the fathead minnow and resulted in a value of 0.8916 mg/L.

Chronic toxicity to aquatic plants is dependent on chemical form of arsenic. Plant values for arsenic (III) range from 2.3 mg/L to greater than 59.2 mg/L, while values for arsenic (V) range from 0.048 mg/L to 202.0 mg/L. Endpoints for arsenic (V) tended toward effects concentrations while arsenic (III) endpoints tended toward lethality concentrations (USEPA, 1985). Sodium arsenate ($AsHN_2O_4$) showed no impact on growth curves of planktonic alga at all concentrations tested (0.05-2.0 mg/L) (Maeda et al., 1983). The toxicity information

available for arsenic suggests that benthic invertebrates are more sensitive to arsenic than are aquatic plants.

3.1.2 Cadmium

Several acute toxicity studies regarding the toxicity of cadmium in aquatic invertebrates and fish have been conducted. The LC_{50} values (median lethal concentration) reported for fish and aquatic invertebrates ranged from 0.000233 mg/L for *Daphnia magna* to 25 mg/L for goldfish at a hardness of 100 mg/L (USEPA, 1980).

The eggs of three aquatic species (goldfish, leopard frog, and largemouth bass) were exposed to cadmium-spiked sediments (2.3 percent organic matter) until four days post hatch (6-7 days total exposure) (Francis et al., 1984). Sediments with 1,000 mg/kg were not toxic to goldfish or leopard frog. However, 25 and 0 percent mortality was reported for largemouth bass at sediment concentrations of 1,000 and 100 mg/kg, respectively.

Following laboratory exposure to cadmium for 3 days, the LC_{50} values for American toad (*Bufo americanus*) tadpoles ranged from 2.87 to 7.84 mg/L (Ferrari et al., 1993). An embryo-larvae laboratory study where Eastern narrow-mouthed toads (*Gastrophryne carolinensis*) were exposed to cadmium for 7 days resulted in an LC_{50} value of 40 mg/L (Birge et al., 1979). Studies with the African clawed frog (*Xenopus laevis*) have shown 2-day LC_{50} values ranging from 3.2 to 11.7 mg/L (USEPA, 1985). Chronic exposures (100 days) with *X. laevis* tadpoles have resulted in toxicity values (development) of 0.65 mg/L (USEPA, 1985).

In the chronic laboratory studies, both developmental and other growth effects resulted for various amphibian species. Following 24 days of exposure to concentrations of cadmium ranging from less than 2 to 504.5 µg/L, a decrease in limb regeneration was seen for northwestern salamander (*Ambystoma gracile*) larvae as cadmium concentration increased (Nebeker et al., 1994). In a separate study, where *A. gracile* larvae were exposed to six concentrations of cadmium, growth was significantly reduced at concentrations of 227 and 535 µg/L (Nebeker et al., 1995). The resulting NOAEL and LOAEL values for this study were 106 and 227 µg/L, respectively.

Cadmium exposure via solution has been shown to be toxic to various plant species, although the following data are based on terrestrial plant species. Spruce seedlings displayed a 23 percent reduction in root elongation when exposed to 0.11 mg/L cadmium (as $Cd\ SO_4$) for 7 days (Lamersdorf et al., 1991). Exposing wheat (*Triticum aestivum*) to cadmium (as $Cd(NO_3)2$) in solution resulted in the measurement of toxicity in multiple endpoints (Ouzounidou et al., 1997). Wheat exposure to 29.8 mg/L resulted in a 53, 40, 42 and 17 percent reduction in root length, shoot-leaf length, root mass, and shoot mass, respectively. Although little data were found for aquatic plant species, the USEPA Region 3 screening value for sediment flora is 5.1 mg/kg (USEPA, 1995), which is higher than the 1.2 mg/kg screening value for sediment fauna, suggesting that benthic invertebrates are more sensitive to cadmium than are aquatic plants.

3.1.3 Copper

The majority of the toxicity information available for copper is based on aqueous exposure studies. Therefore, little information is available on toxicity from sediment-associated copper. Exposure to copper has been shown to affect caddisfly (*Clistoronia magnifica*)

lifecycles (Nebeker et al., 1984). The no observed effect concentration (NOEC) of copper was 0.0083 mg/L, and exposure to 0.013 mg/L copper resulted in significant reductions in adult emergence. Exposure to 0.017 mg/L and greater resulted in 60 and 40 percent larvae surviving to pupae and swimming pupae, respectively, and no adults emerged following exposure to greater than 0.0035 mg/L copper.

In a review of copper hazards to fish, wildlife, and invertebrates, Eisler (1998) found that many species of freshwater plants and animals die within 96 hours at concentrations from 5.0 to 9.8 µg/L copper. Sensitive species of freshwater mollusks, crustaceans, and fishes die at concentrations from 0.23–0.91 µg/L. The acute toxicity data indicate a considerable range of toxic effect values both within and among invertebrate taxa. Crustaceans appear to be most susceptible, with 3-day LC_{50} values of 0.024 mg/L for *Daphnia pulex* and 0.019 to 0.022 mg/L for *Gammarus pseudolimnaeus*. Mollusks are less susceptible, with 4-day LC_{50} values ranging from 0.037 to 2 mg/L depending on the species tested. Four-day LC_{50}s for oligochaetes, rotifers, and chironomid larvae range from 0.1 to 1.7 mg/L (Mance, 1990).

Copper toxicity to aquatic biota is primarily related to the dissolved cupric ion [Cu (II)]. The toxicity of copper in its complexed or adsorbed form is less than that of the free ionic form. In aquatic invertebrates it causes gill damage at high concentrations and in fishes it interferes with osmoregulation. The data presented in Eisler (1998) show that aquatic plants are generally less sensitive to copper than are benthic invertebrates.

3.1.4 Lead

Because of 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. Lead can bioaccumulate in 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 as lead concentrations tend to decrease markedly with increasing trophic level in both detritus-based and grazing aquatic food chains (Wong et al., 1978, as cited in Eisler, 1988).

Lead poisoning in birds is particularly well documented, but most lead poisoning in wild birds results from ingestion of lead pellets. In contrast, lead poisoning of birds, such as raptors, from biologically incorporated lead is considered unlikely. Toxic effects include mortality, reduced growth and reproduction, alterations of blood chemistry, lesions, and behavioral changes.

A study on the toxicological effects of lead ingestion in birds found that an oral dose of 3 mg/kg/day[1] caused a reduction in muscle condition and altered feeding activity of starlings (Osborne et al., 1983). The same dose caused clinical symptoms of lead poisoning in red-tailed hawks (Reiser and Temple, 1981). This dose was considered a LOAEL. A NOAEL was estimated by multiplying the LOAEL by an uncertainty factor of 0.1.

A 7-month study on the toxicological effects of lead ingestion in American kestrels found that an oral dose of 3.85 mg/kg/day did not cause any adverse reproductive effects (summarized in Sample et al., 1996); this dose was considered a chronic NOAEL. A chronic

[1] Units of mg/kg/day are referedenced to kg of body weight (i.e., mg contaminant per kg bodyweight per day)

LOAEL of 38.5 mg/kg/day was estimated by multiplying the chronic NOAEL by an uncertainty factor of 10. A 12-week study with Japanese quail found that oral exposures to lead acetate in the diet did not have any adverse reproductive effects at doses of 1.13 mg/kg/day (chronic NOAEL) although adverse effects were observed at a dose of 11.3 mg/kg/day (chronic LOAEL; Sample et al., 1996).

3.1.5 Mercury

A variety of adverse biological effects have been attributed to mercury. Mercury is a known teratogen, mutagen, and carcinogen. Mercury has been documented as adversely affecting reproduction, growth and development, behavior, blood and serum chemistry, motor coordination, vision, hearing, histology, and metabolism at relatively low concentrations in birds and mammals. Early developmental stages of organisms are the most sensitive to mercury poisoning. The form of mercury most readily assimilated by biota is methylmercury. Once incorporated in tissues, methylmercury is very slow to depurate.

A one-year study conducted on Japanese quail indicated that an oral dose of 0.9 mg/kg/day (as mercuric chloride) caused reduced fertility and egg hatchability (summarized in Sample et al., 1996). This dose was considered a chronic LOAEL. No adverse reproductive effects were observed at a dose of 0.45 mg/kg/day. This dose was considered a chronic NOAEL.

A study conducted on juvenile starlings indicated that a dose of 0.12 mg/kg/day caused kidney lesions (Nicholson and Osborn, 1984). This dose was considered an LOAEL. An NOAEL of 0.01 mg/kg/day was estimated by multiplying the LOAEL by an uncertainty factor of 0.1.

3.1.6 Silver

Silver can be toxic to aquatic organisms. Elevated concentrations can cause growth reduction in juvenile mussels (Calabrese et al., 1984) and adverse effects on reproduction in gastropods (Nelson et al., 1983).

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). The screening value used in the SERA of 1.0 mg/kg is based on an Effects Range Low (ERL) value from Long et al. (1995), which is a conservative value based on results from marine sediments.

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 the 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 complexes 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). Silver can bioconcentrate in aquatic biota and bioaccumulate in plants and animals, but is not expected to biomagnify, and food chain transfer is not expected to be significant (Luoma and Jenne, 1977).

3.1.7 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).

Plant species have different tolerance levels to available zinc. Grasses can tolerate high levels of available zinc, while vegetables are sensitive (Vitosh et al., 1994). Zinc is a micronutrient for plants and is required to sustain regulation of growth, chlorophyll synthesis, carbohydrate formation, and regulate enzymatic reactions and hormonal functions. At higher concentrations, however, zinc can produce toxic effects in exposed organisms. Low levels of zinc (e.g., 3.3 mg/kg) have been shown to decrease the annual ring growth of trees (Hagemeyer et al., 1993). Relatively low concentrations (e.g., 25 and 50 mg/kg) of zinc in soil have also been linked to decreasing seed yields (Sheppard et al., 1993; Aery and Sakar, 1991). The most common effects of zinc toxicity to plants are inhibition of root elongation and reduced growth.

Studies using a variety of benthic macroinvertebrate 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. Further studies with amphipod (*Hyalella azteca*) resulted in a 10-day LC_{50} value of 0.073 mg/L (Phipps et al., 1995).

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.

For fish, slight differences have been shown for bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibosus*) and fathead minnow (*Pimephales promelas*). Following 4 days of exposure to zinc, the LC_{50} values for *L. gibbosus*, *L. macrochirus* and *P. promelas* were 20.1 (Rehwoldt et al., 1972), 12.9 (ANS, 1960) and 0.238 mg/L (Norberg and Mount, 1985), respectively.

Chronic exposure to zinc can result in softening of bone, anemia, enteropathy, and kidney damage. The toxicological effects of zinc ingestion to birds and mammals have been documented in various studies. In a study conducted on white leghorn hens, a dose of 130.9 mg/kg/day caused decreased rates of egg hatchability (summarized in Sample et al., 1996). This dose was considered to be a chronic LOAEL for avian species. No adverse effects were noted at a dose of 14.5 mg/kg/day. This dose was considered to be a chronic NOAEL.

A study conducted on rats indicated that a dose of 160 mg/kg/day of zinc (as zinc oxide) caused no effects during gestation (summarized in Sample et al., 1996). This dose was considered a NOAEL for mammals. However, a dose of 320 mg/kg/day caused reduced fetal growth rates and increased rates of fetal resorption. This zinc dose was considered to be a chronic LOAEL.

3.2 Conceptual Site Model

The conceptual site model (CSM) describes the habitat features of the site, the COC transport and exposure routes, and ecological receptors associated with the site (Figure 3-1). The CSM serves as the basis for selecting assessment and measurement endpoints and for developing a sampling and analysis plan to evaluate those endpoints. The CSM has been revised to reflect the results of the SERA and Step 3A and the decision to address the upland soil and swale sediments through a removal action.

3.2.1 Transport and Exposure Pathways

The primary source of chemicals in soil, sediment, and surface water at Site 28 is believed to be areas where wastes and materials were stored or burned in the past, or where contaminated soil, sediment, or groundwater have been transported and have accumulated. As described above, a soil removal action is planned to remove the primary source of contamination from the site. Although dissolved COCs in the groundwater represent an ongoing source for COC migration to Mattawoman Creek, after the source (contaminated soil and sediment) is removed the concentrations of COCs dissolved in the groundwater should decrease over time.

Ecological receptors include benthic invertebrates, aquatic plants, water column invertebrates, amphibians, and fish in Mattawoman Creek. Receptors may be exposed to chemicals via direct contact with sediments and/or surface water, root uptake, ingestion of sediment and/or surface water, and/or trophic transfer through the food web.

The data gathered to date suggest that some contaminant transport has occurred through soil erosion and surface runoff along the swales and into Mattawoman Creek adjacent to the site, as identified by the elevated concentrations of metals in the stream sediments along the immediate shoreline. Much of the soil at Site 28 is void of vegetation, particularly near the location of the former zinc recovery furnace. As a result, considerable erosion has occurred, resulting in the transport of soil and COCs into Mattawoman Creek. The extent of contaminant migration appears to be limited, however, as the furthest downgradient sample along the Mattawoman Creek shoreline contained concentrations of COCs below risk screening levels.

Additional evidence of possible contaminant migration is the concentrations of metals measured in surface water from the on-site swales. The presence of metals in the surface water likely results from surface runoff from the site and suspension of particulates to which these metals are sorbed. In addition, groundwater is likely discharging to the lower portions of the swales near Mattawoman Creek because a low-permeability clay lens at the base of the slope at Site 28 prevents downward movement of the groundwater. Dissolved metals are present in groundwater at the site, which is likely discharging to the surface water in the swales and ultimately into Mattawoman Creek. Metals in the groundwater

must first pass through sediments in the swales or in Mattawoman Creek at the base of the slope prior to entering the water column. In coarse-grained sediments with little organic matter, the dissolved metals in groundwater will pass directly to the water column. In fine-grained or organically rich sediments, a portion of the groundwater-borne metals may adsorb to sediment particles.

The primary process by which COCs migrate from sediments into the water column are through desorption from sediment particles and resuspension through physical disturbance of the sediments, such as from boat props or high flow during storm events. COCs that are dissolved in groundwater and adsorb onto sediment particles as groundwater discharges up through the sediments may desorb from the sediments over time and may represent a steady source of COC input to the water column.

Once in Mattawoman Creek, the primary migration pathway for COCs that are discharged from groundwater would be diffusion through the water column and bioaccumulation in the food web. Dissolved COCs in the groundwater that are discharged to Mattawoman Creek will be diluted by the larger volume of receiving water in the creek. Diffusion is further increased by the flow of water in the creek moving the diluted COCs out of the discharge zone. However, the potential for adverse effects exists for organisms in close proximity to the discharge point for long periods of time.

3.2.2 Assessment Endpoints

Assessment endpoints for the BERA are as follows:

Survival and growth of the benthic invertebrate community. 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. This assessment endpoint is considered to also be protective of the aquatic plant community because benthic invertebrates are generally more sensitive to the COCs at this site than are aquatic plants.

Survival and growth of finfish. Finfish are susceptible to direct chemical exposure from site sediment and through food chain transfer of bioaccumulative chemicals. Finfish provide an important link between lower and upper-trophic levels of the aquatic food web.

Survival, growth, and reproduction of aquatic omnivorous birds. These receptors are mid-level consumers and are thus susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify through aquatic foodchains. The mallard (*Anas platyrhnchos*) was chosen to represent this assessment endpoint. Mallards utilize shallow wetland habitats, preferring freshwater to saltwater or brackish water bodies. Their diet consists mainly of aquatic plants, but aquatic insects, mollusks (mostly snails and small bivalves) and crustaceans are also important dietary components. Through foraging, mallards may ingest soil and sediment.

In the spring, mallards shift from a largely herbivorous diet to a diet containing a high proportion of invertebrates to obtain protein for their prebasic molt and then for egg production. Laying females consume a higher proportion of animal foods on the breeding grounds (about 67% of the diet) than do male or non-laying females (about 40% of the diet).

This dietary shift continues throughout the summer, as many females lay clutches to replace destroyed nests. Ducklings consume aquatic invertebrates almost exclusively, particularly during the period of rapid growth, and juveniles in late summer may still be consuming approximately 90 percent animal matter (Swanson and Duebbert, 1989; USEPA, 1993).

This assessment endpoint is also considered to be protective of aquatic insectivorous birds such as tree swallow (*Tachycineta bicolor*). Tree swallows utilize open areas over water during most of the year and feed almost exclusively on emerging and flying insects.

Survival, growth, and reproduction of piscivorous birds. These receptors are top-level consumers and are thus susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify through aquatic foodchains. The great blue heron (*Ardea herodias*) was chosen to represent this endpoint. Great blue heron usually nest in colonies near their foraging habitat. These birds prefer the shallow edges of freshwater and saltwater lakes, rivers, and wetlands, especially those areas that support their major food source of small fish and amphibians.

Survival, growth, and reproduction of piscivorous mammals. These receptors are top-level predators and are susceptible to exposure to bioaccumulative chemicals, especially those that have the potential to biomagnify through aquatic foodchains. The mink (*Mustela vison*) was chosen to represent this assessment endpoint. Mink live in both freshwater and saltwater aquatic and wetland habitats and prefer irregular shorelines. Mink are opportunistic and feed nocturnally on whatever prey are available including small mammals, aquatic plants and invertebrates, fish, and amphibians.

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 judgment of risk assessors. The risk hypotheses/questions associated with the assessment endpoints are:

1. Are the concentrations of arsenic, cadmium, copper, lead, or zinc in sediment at Site 28 impairing the survival or growth of benthic invertebrates in shoreline sediments to the extent that the prey base to support finfish has been adversely affected?
2. Are lead, mercury, or zinc bioaccumulating in the food web and impairing the survival, growth, or reproduction of finfish or upper-trophic-level receptors?
3. Is the silver in the sediments of Mattawoman Creek along the opposite shore impairing the survival or growth of benthic invertebrates to the extent that the prey base to support finfish has been adversely affected?

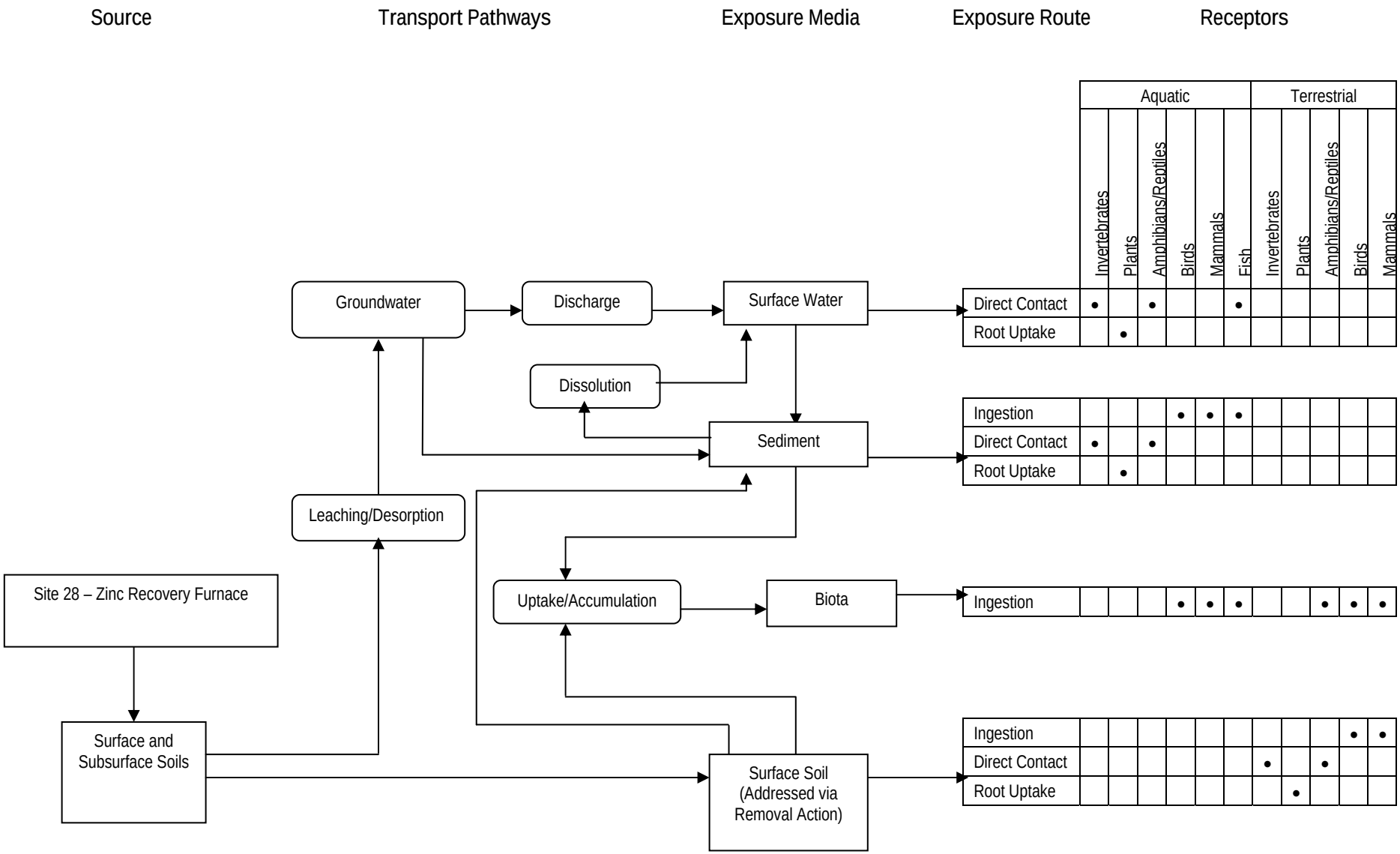

FIGURE 3-1. CONCEPTUAL SITE MODEL
NDWIH Indian Head – Site 28

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 28, measurement endpoints associated with each assessment endpoint are defined as follows:

Assessment Endpoints	Measurement Endpoints
Evaluate the survival and growth of the benthic invertebrate community and its ability to function as a prey base for finfish.	Results of 28-day sediment toxicity tests (survival and growth) with the amphipod *Hyalella azteca*, using site, reference, and control sediment to evaluate the status of the benthic invertebrate community as a prey base for finfish. Comparison of the abundance of benthic invertebrates in site sediment with abundance of benthic invertebrates in reference sediment.
Evaluate the potential for adverse changes in the survival, growth, and reproduction of finfish and piscivorous wildlife that utilize the site.	Comparison of estimated exposure doses to toxicity reference values using site-specific bioaccumulation data obtained from COC concentrations in fish tissue from the site to a reference HQ of 1.0. Comparison of COC concentrations in fish tissue from the site with tissue residue effects values from the literature and with background fish tissue concentrations collected from an upstream reference site.
Evaluate the potential for adverse changes in the survival, growth, and reproduction of omnivorous birds that utilize the site.	Comparison of estimated exposure doses to toxicity reference values using the site-specific bioaccumulation data obtained from COC concentrations in benthic invertebrate tissue (from 28-day bioassays with *Lumbriculus variegatus*) to a reference HQ of 1.0. Mallard exposure assessment will be based on 67% animal diet during nesting period for females.

4.2 Study Design

This section presents the scope of the additional sampling planned for Site 28 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

Toxicity tests will be performed with benthic invertebrates to evaluate the potential risk posed by COCs in site sediment to ecological receptors. Chemical analyses of sediment will support the toxicological analyses. A control will be run for each organism to ensure that representatives of the population used in the toxicity testing are 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.

Benthic Invertebrates

The ability of the sediment to potentially support a viable benthic invertebrate community will be assessed by evaluating growth and survival data from bioassays conducted on surface sediment collected at the site and from an upstream reference area. *Hyalella azeteca* (amphipod) will be used for sediment toxicity testing. This organism was selected because its use is widely accepted for sediment bioassays and it is tolerant of a wide range of grain sizes. Additionally, this species is more sensitive to copper, lead, and zinc than is *Chironomus tentans* (midge) (ASTM, 2000; USEPA, 2000).

The potential risk to omnivorous birds that feed on benthic organisms at the site will be assessed by performing 28-day bioaccumulation assays with sediment from the site and from an upstream reference area. *Lumbriculus variegatus* (*L. variegatus*) (oligochaete) will be the test organism used for this bioassay. *L. variegates* is found throughout North America and prefers shallow habitats at the edges of ponds, lakes, or marshes where it feeds on decaying vegetation and microorganisms, thus making it a representative benthic invertebrate component of the mallard diet.

Sediment Sample Locations

The spatial distribution of the COCs in sediment was discussed in Sections 2.3.2 and 2.3.4. Sample IS28SD05 had some of the highest concentrations of COCs of all the sediment samples. This sample was collected on the shoreline where Swales 1-3 discharge to Mattawoman Creek. The data suggest that offsite migration of COCs may be more considerable in this area of the site (where Swales 1-3 are located), relative to the Swale 4 area. A pilot metals sequestration demonstration project is currently being conducted for shoreline sediments in the area between samples IS28SD04 and IS28SD05 (Neptune and Co., 2004). The sediments in this area have been shown to be acutely toxic to benthic invertebrates. A bulk sediment sample was collected in the vicinity of IS28SD05 as part of the Toxicity Identification Evaluation (TIE) Study (SAIC, 2001) in which 0 percent survival was observed in a 10-day *Hyalella azteca* test. Similarly, a sediment sample from the untreated plot area of the ongoing metals sequestration demonstration project (between samples IS28SD04 and IS28SD05) showed 0 percent survival in a 10-day *H. azteca* test (an update on the demonstration project given at the February 2005 meeting of the IHIRT). These results demonstrate that the sediments along the shoreline of Site 28 in the area between IS28SD04 and IS28SD05 are acutely toxic to benthic invertebrates.

The concentrations of COCs in the other samples collected along the shoreline generally decline in the downstream direction (i.e., from IS28SD03 to IS28SD01). Therefore, to evaluate potential risk to the benthic community, these three sampling locations (IS28SD01,

IS28SD02, and IS28SD03) will be resampled and submitted for bulk sediment toxicity testing.

Two sediment samples will also be collected from the depositional bar across the creek from the site. The two samples in this area contained the highest concentrations of silver, which was the only COC identified for the benthic invertebrates community in this area. The proposed sediment sampling locations are shown in Figure 4-1. The sediment samples will be collected from a depth of 0 to 6 inches below the sediment/water interface to ensure that the biologically active zone is captured.

Reference Samples

The response of organisms to reference and control sediment will be statistically compared to the response of organisms exposed to site sediment. The response of organisms exposed to reference media will be used to evaluate whether any observed toxicity may be site-related or reflective of ambient conditions in Mattawoman Creek. The health of the test organisms used for the bioassays will be evaluated by control performance criteria for each test. Care will be taken to collect an appropriate reference media sample (i.e., having similar physical characteristics as the site medium). The similarities and differences between each reference area (if differences in site sediment warrant more than one reference location) and the group of samples it is used for will be described and presented in the BERA report.

The reference location will likely be in the vicinity of a freshwater sediment sampling location previously used as a reference sample for NDWIH Sites 11-17, which is located approximately one-half mile upstream of Site 28 (Figure 4-2). Care will be taken to ensure that the reference sediment falls within the range of the physical characteristics of the site sediment (i.e., similar grain size and amount of organic material).

4.2.2 Site-Specific Bioaccumulation Data

To assess potential risks to aquatic omnivorous birds, 28-day bioaccumulation bioassays with the invertebrate (*L. variegatus*) will be conducted for the three sampling stations along the shoreline of Site 28. The invertebrate tissue will be analyzed for TAL metals and percent moisture. The chemical data will be used as input to a food chain model as described in the SERA (CH2M HILL, 2005) and HQs will be calculated.

To more accurately quantify the risk to fish and piscivorous birds, forage-size (<6 inches) epibenthic fish will be collected from the littoral zone along the shoreline of Site 28, particularly in the area where the swales discharge to Mattawoman Creek. To more accurately quantify the risk to piscivorous mammals, larger fish (approximately 8 to 12 inches) will be collected from the littoral zone along the shoreline of the site. The forage-size fish sample will be submitted for whole-body chemical analysis (TAL metals and percent moisture), while the larger fish will be de-boned and only the tissue will be analyzed because mink generally do not consume fish whole. *Fundulus* spp. will be collected preferentially for the piscivorous bird sample, if present in abundance, because these fish have relatively small home ranges and feed on a variety of benthic invertebrates. The lengths and weights of the fish in the sample will be recorded. The tissue residue data will then be used as input to a food chain model as described in the SERA (CH2M HILL, 2005). Fish COC concentrations will also be compared with tissue residue data from fish collected at the reference site (forage-size fish) and with fish tissue residue data from the

Mattawoman Creek Study (TetraTech NUS, 2002) and with tissue residue data from the literature associated with adverse effects.

4.2.3 Benthic Invertebrate Community Abundance

The evaluation of the benthic invertebrate community will provide a measure of its ability to function as a prey base for finfish and other wildlife. Measures of abundance are more relevant than measures of community structure when evaluating the ability of the benthic invertebrate community to function as a prey base for higher-trophic-level receptors. Therefore, benthic grab samples will be collected from each sediment sampling location and the macroinvertebrate community will be described, with emphasis on overall abundance relative to reference as the measurement endpoint.

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 process 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, where probabilistic hypotheses with confidence limits cannot be formulated; therefore, simple optimization rules cannot be followed (Barnthouse and Suter, 1996). The steps of the DQO process for the Site 28 BERA investigation are described below.

Step 1. State the Problem

The data gathered to date suggest that concentrations of eight inorganics (antimony, cadmium, copper, lead, mercury, nickel, silver, and zinc) are elevated in surface soils at the site, likely because of past disposal activities and historical burning. The data further suggest that some contaminant transport has occurred through surface runoff along the drainage swales and into Mattawoman Creek, as identified by the elevated concentrations of arsenic, cadmium, copper, lead, silver, and zinc in the sediments. Additional evidence of possible contaminant migration includes the concentrations of cadmium and zinc above ecological screening criteria in surface water from the site swales.

As described in Section 2.3, a soil removal will be conducted to address human health and ecological risks for the upland and swale areas of the site, and further evaluation of potential ecological risks from COCs in surface water will be deferred until after the soil removal action is completed. Therefore, this work plan is focused solely on evaluating potential ecological risks from COCs in sediments of Mattawoman Creek adjacent to the site.

Evaluation of the data collected to date indicates that potential risks exist to benthic invertebrates from arsenic, cadmium, copper, lead, silver, and zinc; to water column receptors from cadmium and zinc; and to upper-trophic-level semiaquatic receptors from lead, mercury, and zinc.

Step 2. Identify the Decisions

Primary Question:

What are the baseline ecological risks related to COCs in the sediment at Site 28?

Secondary Questions:

- Are the concentrations of arsenic, cadmium, copper, lead, or zinc in sediment at Site 28 impairing the survival or growth of benthic invertebrates in shoreline sediments to the extent that the prey base to support finfish has been adversely affected?
- Are lead, mercury, or zinc bioaccumulating in the food web and impairing the survival, growth, or reproduction of upper-trophic-level receptors?
- Is the silver in the sediments of Mattawoman Creek on the depositional bar (located approximately 150 feet from the Site 28 shoreline) impairing the survival or growth of benthic invertebrates to the extent that the prey base to support finfish has been adversely affected?

Step 3. Identify Inputs to the Decision

1. Results of previous sampling events
   - In surface sediment, concentrations of arsenic, cadmium, copper, lead, silver, and zinc are elevated relative to background, posing a potentially unacceptable ecological risk.
   - Lead, mercury, and zinc are COCs for upper-trophic-level receptors and thus pose a potentially unacceptable ecological risk.
2. Sediment toxicity testing (risk to benthic invertebrates)
   - Sediment chemistry to support interpretation of the toxicity testing
   - Bulk sediment toxicity
3. Tissue Analysis
   - COC residues in benthic invertebrate tissue (obtained from bioassay)
   - COC residues in fish tissue (obtained from site samples)
4. Benthic Invertebrate Community Abundance
5. ERA Exposure Models
   - COC residues measured in tissue will be used to replace modeled values used in Step 3A to estimate risk to upper-trophic-level receptors.

Step 4. Define the Study Boundaries

1. COCs in sediment include arsenic, cadmium, copper, lead, silver, 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 invertebrates by higher-trophic-level consumers can facilitate movement of contamination through the food chain.
3. The sediment reference location will likely be in the vicinity of a freshwater sediment sampling location previously used as a reference sample for NDWIH Sites 11-17.

Step 5. Develop Decision Rules

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

- **Bulk Sediment Toxicity**. The growth and survival of test organisms (i.e., benthic invertebrates) 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. If no significant adverse effects are found in any of the samples, then the sediment will be considered nontoxic to the benthic invertebrate community.
- **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.
- **Benthic Invertebrate Community Abundance.** Benthic invertebrates found in site sediments will be evaluated as a prey base for the finfish community. Species richness and abundance metrics will be used to evaluate the benthic community at each sampling station relative to the reference location. The metric values will be used as an additional line of evidence and evaluated in context with the sediment chemical and bioassay results to evaluate potential exposure-response gradients.

Fish Communities. The following criteria will be used to weigh the results of the sampling effort to assess potential risk to the fish communities.

- **Fish Tissue Residues**. The COCs measured in fish tissue collected at the site will be compared with reference fish tissue results from the reference site and from the Mattawoman Creek Study (TTNUS, 2002) and with critical residue values from the literature. Exceedance of critical tissue residues and reference tissue levels will constitute a risk to the finfish community at the site. If critical residue values are exceeded, but not reference tissue levels for the same COC, then the risk will not be considered site-related, but rather representative of background risk levels.

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 at Site 28.

- **Benthic Invertebrate Tissue Analysis.** The COCs measured in the oligochaete tissue from the bulk sediment toxicity tests will be used to model exposure to omnivorous birds (i.e., mallard). Unacceptable risk will be constituted by exceedance of LOAEL-based reference toxicity values for these receptors.

- **Fish Tissue Analysis.** The COCs measured in the fish tissue from the sample collected at the site will be used to model exposure to piscivorous birds and mammals (i.e., great blue heron and mink). Unacceptable risk will be constituted by exceedance of LOAEL-based reference toxicity values for these receptors.

If unacceptable risks are identified for receptors, attempts will be made to use the site-specific bioaccumulation data derived from the chemical analyses in conjunction with the toxicity data to deriving a toxicity threshold to support any remedial cleanup goals for the site, if warranted.

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 28.

Baseline Decision Rule Errors:

- Deciding that the COCs in the media at Site 28 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 28 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 $\alpha = 0.05$.

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 28 was described in Section 4.2. The uncertainty in the risk to the benthic invertebrate and finfish community will be reduced through the results of the data collection.

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 measured in benthic invertebrates and finfish. These data will provide more accurate estimates of the bioavailability and bioaccumulation potential of COCs in the site media, rather than relying on bioaccumulation factors from the literature. Therefore, the outcome of this effort should provide a realistic baseline estimate of ecological risk to upper-trophic-level receptors that forage at the site.

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

In addition, at each point in which analyses are based on assumptions, conservative, non-compensating assumptions will be used to minimize the possibility of decision errors.

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IS28SD03006

Total Metals	MG/KG	MG/KG
Aluminum	3270 J	1250 J
Arsenic	14.8 J	7.8 J
Barium	35.6 J	8.8 J
Cadmium	9.5 J	6 J
Chromium	14.3 J	5.9 J
Cobalt	4.7 J	1.4 J
Copper	51.7 J	18.5 J
Lead	423 J	321 J
Manganese	351 K	26.4 K
Mercury	0.09 B	0.04 B
Nickel	16.2 J	2.8 J
Silver	ND	ND
Vanadium	13.8 K	7.6 J
Zinc	8190 J	4440 J

IS28SD02006

Total Metals	MG/KG	MG/KG
Aluminum	1970	5660 J
Arsenic	11.4	58.1 J
Barium	16.6 J	75
Cadmium	ND	28 J
Chromium	9.6	8.2 J
Cobalt	2.2 J	4.8 J
Copper	3.8 J	41.3 J
Lead	20.7 K	278 J
Manganese	40.6	89.6 K
Mercury	0.05 B	0.38
Nickel	4.6 J	8.1 J
Silver	1.1 J	ND
Vanadium	7.9 J	10.5 J
Zinc	138	7480 J

IS28SD13006

Total Metals	MG/KG	MG/KG
Aluminum	14200	14900
Arsenic	7.9 K	4.9 K
Barium	112	110
Cadmium	ND	ND
Chromium	26	24.7
Cobalt	13.2 J	12.3 J
Copper	23 K	13.8 K
Lead	27.9 K	16 K
Manganese	891	481
Mercury	0.35 B	0.16 B
Nickel	17.6 J	18.5 K
Silver	3.3 J	2.7 J
Vanadium	33.6 K	30.7
Zinc	117	63

IS28SD01006

Total Metals	MG/KG	MG/KG
Aluminum	1910	1290
Arsenic	0.96 B	0.67 B
Barium	17.9 J	13.5 J
Cadmium	ND	ND
Chromium	3.4 K	5.9
Cobalt	3 J	3.9 J
Copper	2.8 B	1.7 B
Lead	7.6 K	3.7 K
Manganese	28.7	14.3
Mercury	0.04 B	0.02 B
Nickel	4.9 J	ND
Silver	ND	ND
Vanadium	7.5 J	5.6 J
Zinc	11.9	5.1 K

IS28SD11006

Total Metals	MG/KG	MG/KG
Aluminum	11700	10500
Arsenic	8.2 K	7.3 K
Barium	95.5	90.5
Cadmium	ND	ND
Chromium	23	20.1
Cobalt	12.6 J	11.4 J
Copper	23.9	24.3
Lead	36.7 K	35.8 K
Manganese	397	412
Mercury	0.44 K	0.11 B
Nickel	20.2 K	20.5 K
Silver	4 J	3.8 J
Vanadium	32.1 K	31.4 K
Zinc	159	116

LEGEND

- Sediment Sample Location
- Zone Boundary
- Fence Line
- IR Site
- Five foot Contours
- One Foot Contours
- Buildings
- Railroads
- Roads

N

0 75 150 Feet

Figure 4-1
Proposed Sediment Samples
Site 28 BERA Workplan
NDWIH Indian Head, Maryland

CH2MHILL

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LEGEND
Sediment sample location

N

0 150 300 Feet

Figure 4-2
Reference Sample Location
Site 28 BERA Work Plan
NDWIH, Indian Head, Maryland

CH2MHILL

SECTION 5

Sampling and Analysis Plan

The Sampling and Analysis Plan comprises 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 Sediment

Sediment will be collected from five locations at Site 28, as described in Section 4.2.1.2 (Figure 4-1). The samples will be collected as close as possible to the original sampling locations. The samples will be collected from 0 to 6 inches below the sediment/water interface with a decontaminated trowel or auger. Approximately 8 L of sediment will be collected and homogenized to a consistent color and texture in a decontaminated stainless steel bowl.

The sediment samples will be submitted for both bulk sediment toxicity testing and chemical analysis. 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. The chemistry samples will be analyzed for TAL metals, pH, TOC, sulfide, and grain size (by sieve analysis).

A 28-day bulk sediment toxicity test (growth and survival endpoints) with the amphipod *H. azteca* will be conducted for each sample and a 28-day bioaccumulation test with the oligochaete *L. variegatus* will be conducted for the three sample stations along the immediate shoreline (IS28SD01, IS28SD02, and IS28SD03) and the reference station. Ammonia concentrations will be monitored during the toxicity tests to ensure that ammonia buildup does not confound the test results. 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.

5.1.2 Tissue Samples for Site-Specific Bioaccumulation Data

Forage-size epibenthic fishes will be collected from the littoral zone along the shoreline of Site 28 and from the reference location using a beach seine and/or minnow traps. The larger fish will be collected using trap nets and/or gill nets. Two composite samples, one consisting of at least 10 fish (forage size) of the same species and the other comprising at least 3 fish of the large size will be submitted for whole-body chemical analysis (TAL metals and percent moisture). *Fundulus* spp. will be collected preferentially for the forage-size sample, if present in abundance, because these fish have relatively small home ranges and feed on a variety of benthic invertebrates. The species collected for the larger-sized sample

will be determined based on which species are caught at the site. The lengths and weights of the fish in the samples will be recorded.

5.1.3 Benthic Community Grab Samples

Benthic community samples will be collected at each sampling station using a petite Ponar dredge. Three replicate grabs will be collected at each sampling station. The grab samples will be sieved (500-µm mesh) in the field. Each grab sample will be preserved in the field using a 5 percent formalin solution and shipped to a biological laboratory for identification and enumeration.

5.1.4 Reference Samples

The sediment reference location will likely be in the vicinity of a freshwater sediment sampling location previously used as a reference sample for Sites 11-17. The physical characteristics of the sediment at this location closely resemble those of the sediment along the depositional bar across from Site 28. The sediments along the immediate shoreline of the site may have higher sand and gravel content; thus, a second reference location might be required. The need for a second reference location will be assessed in the field during the sampling effort. The reference sediment sample(s) will be analyzed for TAL metals, pH, TOC, sulfide, and grain size. Sediment pH and redox potential will be measured in situ, if possible.

5.1.5 Sample Summary

A sampling summary is provided below, by matrix.

Summary of Samples to be Submitted to the Laboratory

Matrix	Laboratory Parameter	Samples	Field Duplicates	Field Blanks	Equipment Blanks	Matrix Spikes	Total Samples
Sediment	TAL metals	6	1	—	1	1/1	10
	TOC	6	1	—	—	—	7
	pH	6	1	—	—	—	7
	Sulfide	6	1	—	—	—	7
	Grain size (sieve)	6	—	—	—	—	6
Tissue- Fish	TAL metals	3	—	—	—	1/1	5
	Percent moisture	3	—	—	—	—	3
Benthic Grab	Benthic Metrics	18	—	—	—	—	18
Toxicity Testing							
Sediment	Toxicity test	6	—	—	—	—	6
Sediment	Bioaccumulation test	4	—	—	—	—	4

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
TOC	Lloyd Kahn Method
pH	SW-846 Method 9045
Sulfide	EPA Method 376.1/ 9030
Grain Size	ASTM D-422 (sieve analysis, include graph, no hydrometer)
28-day Toxicity Test (*H. azteca*)	ASTM (2003) E1688-00 / EPA (2000) EPA/R-99/064
28-day Bioaccumulation (*L. variegatus*)	ASTM (2003) E1688-00 / EPA (2000) EPA/R-99/064

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. 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 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., S28 = Site 28)

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 Sample—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:

IS28SD040001 The 4th surface sediment sample collected at Site 28 from 0 ft to 1 ft bgs

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

IS28EB061505 Equipment blank collected at Site 28 on June 15, 2005

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 28 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 Project Reporting

The methods, results, analyses, and risk characterization will be presented in a Baseline Ecological Risk Assessment report. 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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