REVISED FINAL

REPORT ON THE BIOLOGICAL FIELD-TRUTHING EFFORT AT WINKLEPECK BURNING GROUNDS

at

RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO

Prepared cooperatively by

US Army Corps of Engineers®

SAIC®

LOUISVILLE DISTRICT

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SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Science Applications International Corporation (SAIC) has completed the Revised Final Report on the Biological Field-Truthing Effort at Winklepeck Burning Grounds at the Ravenna Army Ammunition Plant, Ravenna, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of comment response package data quality objectives; technical assumptions; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

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REPORT ON THE BIOLOGICAL FIELD-TRUTHING EFFORT AT WINKLEPECK BURNING GROUNDS AT RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO

Revised Final document prepared in a cooperative effort by

U.S. Army Corps of Engineers
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and

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ABSTRACT

This report describes the field sampling and results whose purpose was to determine whether soil contaminants and their respective hazard quotients (HQs) at Winklepeck Burning Grounds (WBG), Ravenna Army Ammunition Plant, Ravenna, Ohio, have affected plants and animals or whether they are without affect. Constituents that failed the original plant and mammal HQ screen were recalculated as part of this investigation.

This field activity had two primary study objectives. Study objective 1 was to demonstrate the presence or absence of ecological effects in the plants and small mammals at WBG, compared with reference sites. Reference sites qualified for their intended purposes based on statistical analysis and ecological toxicity screen. Study objective 2 was to develop cleanup levels based on soil-plant relationships using data derived from the field sampling.

Based on the observed vegetation abundance, (percent cover, stem density, and biomass), and the hazard quotient re-screen, it does not appear that the chemical contaminants at the pad scale are impairing the vegetation at WBG. For one of the three plant community composition metrics—exotic species—there was an adverse impact, but for the other two metrics (species richness and diversity index), there was no adverse impact. High concentrations of explosives [HMX, RDX, 1,3,5-trinitrobenzene, and 2,4,6-trinitrotoluene (TNT)] and cyanide appeared to cause a decrease in vegetation abundance (percent cover, stem density, and biomass) and an increase in the percent of exotic species at the plot scale. The plot scale refers to small, 1-m by 1-m, units of habitat. High concentrations of metals were, in general, associated with increased vegetation abundance, especially at pad pair 58/59. Copper was associated with decreased vegetation abundance at pad pair 37/38. High concentrations of metals did not consistently cause an adverse ecological effect on vegetation at WBG.

Based on the observed community of small mammals and the weight-of-evidence for specific reproductive ability (sperm count, motility, and morphology) and success of two species measured (white-footed mice and meadow voles), it does not appear that the chemical contaminants are impacting the small mammals within the WBG. This conclusion is based on the results of the trapping, the hazard quotient re-screen results, and the weight-of-evidence propositions.

Regarding study objective 2, numerical modeling of soil chemical concentrations was conducted to develop plant protection levels (PPLs) from the dose-response data for the following chemicals: copper, cyanide, 1,3,5-trinitrobenzene, and TNT. These PPLs represent soil concentrations below which there is no measurable effect on plant abundance and composition. If a site has no ecological impact, then the arithmetic mean soil concentrations (inside the pad boundaries) at that site may be used as a qualitative reference value for other sites that have similar soil, habitat, and chemical contamination. Qualitative reference values represent soil concentrations associated with no measurable effect on plant abundance and composition and are, thus, potential PPLs. The future decision to extrapolate the various types of PPLs from WBG to other sites is a risk assessment recommendation and a risk management decision.

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ACRONYMS

AOC	area of concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	contaminant of concern
COPC	contaminant of potential concern
COPEC	contaminants of potential environmental concern
CV	coefficient of variation
DNA	deoxyribonucleic acid
DNB	dinitrobenzene
DNT	dinitrotoluene
EDQL	Ecological Data Quality Level
EPA	U.S. Environmental Protection Agency
EPL	ecological protection level
ERA	Ecological Risk Assessment
ESV	Ecological Screening Value
FS	Feasibility Study
GPS	Global Positioning System
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	hazard quotient
IDW	investigation-derived waste
IVOS	Integrated Visual Optics System (for Rodent Sperm Analysis)
MTCA	Model Toxics Control Act
NAD	North American Datum
NE	northeast
NOAEL	no observed adverse effect level
NW	northwest
ORNL	Oak Ridge National Laboratory
OSC	Operations and Support Command
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PPL	plant protection level
ppm	parts per million
PRG	preliminary remediation goal
QA	quality assurance
QC	quality control
QMP	Quality Assurance Management Plan
RCRA	Resource Conservation and Recovery Act of 1976
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RI	Remedial Investigation
RSA	Rodent Sperm Analysis
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SD	significant difference
SE	southeast
SOP	Standard Operating Procedures
STL	Severn Trent Laboratories
SVOC	semivolatile organic compound
TCLP	Toxicity Characteristic Leaching Procedure

TNB	trinitrobenzene
TNT	trinitrotoluene
TRV	toxicity reference value
UCL	upper confidence limit
UTL	upper tolerance limit
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
UXO	unexploded ordnance
VOC	volatile organic compound
WBG	Winklepeck Burning Grounds

EXECUTIVE SUMMARY

This report describes the rationales, methods, field sampling results, analyses, discussion and uncertainties, and summaries for studies conducted on vegetation, small mammals, and soil at Winklepeck Burning Grounds (WBG), Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio. A previous screening-level ecological risk assessment, using the hazard quotient (HQ) methodology, indicated a high potential for adverse ecological effects from certain contaminants (explosives, metals, and semivolatile organic compounds) at some burning pads at WBG. Historical operations at WBG include thermal treatment of munitions, disposal of bulk explosives and propellants, and disposal of explosives-contaminated combustible wastes using open burning. Prior to 1980, wastes disposed by burning included hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), antimony sulfide, Composition B, lead oxide, lead thiocyanate, 2,4,6-trinitrotoluene (TNT), propellant, black powder, sludge and sawdust from load lines, and domestic wastes. Also disposed were small amounts of laboratory chemicals and waste oil. The previous computations included all the chemicals, but because HQs are not precise measures of risk, the field-truthing effort applied at WBG was developed in an attempt to identify population- or community-based ecological *effects* in the field, should these be present. This explanation was expressed as the hypothesis that measurable ecological effects from chemical contaminants had occurred.

There were two objectives of the study. The first was to document and compare, with strong statistical assurances and/or weight-of-evidence analysis, measures of vegetation and small mammals on burning pads (that were subjected to chemical contaminants due to waste disposal operations) with similar measures of vegetation and small mammals at nearby reference sites (not subjected to chemical contaminants due to waste disposal operations). The second objective was to gather field-observed data for the development of remedial goal options, or ecological cleanup goals, at WBG. To accomplish this objective, the concentrations of chemicals in soils were measured at selected places at the burning pads, and the chemical concentrations were related to vegetation status according to specific vegetation measurements.

Six study sites (three paired burning pad sites and three paired reference sites) were included in the May through August 2000 biological sampling events. The soils at the reference sites were sampled in May 2002. The May 2002 sampling was designed to document chemical concentrations in soils at the reference areas to better establish their suitability for use as comparison sites to WBG pads.

The three pairs of burning pads selected for the field-truthing effort at WBG are pads 37 and 38, pads 58 and 59, and pads 66 and 67. Pairs of burning pads were used to provide a large enough area for a range of vegetation conditions and for small mammal home ranges. After field surveys, three paired reference sites (E1/E2, S1/S2, and J1/J2) were selected as comparable matches to the three pairs of burning pad sites at WBG based on habitat and similar degrees of disturbance (land use) in non-area of concern settings.

The reference sites qualify for their intended purposes. The comparison of chemical concentrations at the reference sites with the facility-wide background concentrations and ecological screening values (ESVs) indicated that the reference sites and background locations are similar. Further, the chemicals that are of ecological concern at the WBG sites were not present at the reference sites at levels that would produce discernible consequences. Convincingly, explosives and propellants—present at WBG—were not detected at any of the reference sites. The reference sites had low concentrations of some organics and the metals of primary concern at WBG, cadmium and lead. Almost all elevated metal concentrations and detected organic compounds were within the range of ESVs. This means that those chemicals that were present at the reference site were not present at concentrations that would be expected to cause ecological harm. There was evidence of a minor exceedance of iron above background, and no ESVs were available. This was expected because the reference sites were likely not pristine based on the need to be physically

impacted to a similar degree as the WBG pads. Those few chemicals that exceeded the ESVs at the reference sites also exceeded ESVs in the RVAAP facility-wide background samples. In short, each of the reference sites was appropriately selected not only from a soil, vegetation, topographic, and use-history viewpoint, but also from a chemical concentration viewpoint.

Regarding study objective 1, the biological field-truthing effort at WBG included carefully designed field measurements at the pad scale, statistical analysis, weight-of-evidence analysis and discussion, and uncertainty evaluation. The pad scale refers to units of habitat about the size of a burning pad or about 15 m by 30 m when referring to pad pairs 58 and 59 and smaller for pad pairs 66 and 67 and larger for pad pairs 37 and 38. The following conclusions and summary concerning vegetation may be drawn from these efforts:

- The field-truthing approach provided valuable information that reduces concern raised by the HQs. Thus, the observed facts and weight-of-evidence support the absence of concern for vegetation at the scale of the pads. There was much evidence that vegetation is not affected when compared to the reference sites.
- The chemical contamination in the soil at WBG has not caused an ecological impact on the vegetation abundance (percent cover, stem density, and biomass) at the pad scale.
- The chemical contamination in the soil at WBG has not caused an ecological impact on the plant community composition with respect to species richness and species diversity at the pad scale.
- The chemical contamination in the soil at WBG has caused an ecological impact on the plant community composition with respect to the percent of exotic species. The percent of exotic species was higher at the WBG pad pairs than the respective reference sites.
- Constituents that failed the original HQ screen were re-calculated based on the use of an upper confidence interval (95%) on the arithmetic mean instead of the highest detect and use of the reasonable, rather than most conservative, ecological benchmark from an updated soil screening hierarchy. Metals having HQs that ranged between 1 and 30 and were common to all pad pairs sites included As, Cr, Pb, V, and Zn. These HQs are now associated with respective soil contamination at WBG that has not caused an ecological impact on the vegetation abundance and community composition at the pad scale.
- Based on the observed vegetation abundance (percent cover, stem density, and biomass), it does not appear that the chemical contaminants are impairing the vegetation at WBG. For one of the three plant community composition metrics-exotic species-there was an adverse impact, but for the other two metrics, (species richness and diversity index), there was no adverse impact.

The biological field-truthing effort for small mammals at WBG included carefully designed field measurements, weight-of-evidence analysis, and a discussion and uncertainties section. Primarily based on poor capture success, direct quantitative comparisons of the results obtained for the reference areas and burning pad pairs could not be made. The following qualitative conclusions and summary concerning small mammals may be drawn from these efforts:

- The weight –of-evidence suggests that white-footed mice and meadow voles are capable of and are reproducing on and around chemically contaminated areas of the WBG. This is based on both the number and diversity in the community of small mammals observed, including lactating females, and the comparison of male reproductive parameters (sperm counts, motility, and morphology) to published values.
- The chemical contamination may have had an effect on liver and body weight. However, neither physical parameter is known to be indicative of negative effects in small mammals.

- There was evidence of community structure at both the WBG pads and reference sites. For example, various small mammals were captured at both the reference locations and pad pairs including six small animal species that were trapped on the pads.
- No short-tailed shrews were captured in the contaminated WBG pads. However, short-tailed shrews were captured at all reference locations. In addition, one shrew, the relatively uncommon masked shrew believed to be sensitive to environmental stressor, was trapped at WBG.
- Re-screening of HQs for small mammals indicates much lower risk than the original screen. The magnitude of possible hazards to small mammals is needed, as the new HQ values are important for decision making. Specifically, HQs for the mouse, specific to metals and some explosives, were lower than one. Additionally, the shrew HQs for specific metals (As, Ba, Cd, or Hg) ranged from 1 to 6 while their HQ for RDX exceeded 100.
- Conclusions for determining whether there is an adverse impact on small mammals resulting from the exposure to contamination at WBG are less certain then those drawn for vegetation. The weight-of-evidence suggests that it does not appear that the chemical contaminants are impacting the small mammals within the WBG. This conclusion is based primarily on the low HQ values and on the results of trapping, and the weight-of- evidence propositions.

For study objective 2, nine plots were selected for soil and vegetation sampling at each WBG pad pair such that three plots represented sparse vegetation cover (0 to 29%), three represented medium cover (30 to 69%), and three represented high cover (70 to 100%). The measurements for the nine plots at each pad pair were examined visually and statistically for correlations between the soil concentrations and each of the vegetation metrics. Visually means inspection of the scatter of the data points in an x,y plot. Statistically significant correlations, probability (p) < 0.05, were taken as evidence of a potential for a cause/effect relationship between the soil concentrations and the vegetation. The geographical scale is the plot, or approximately 1-m by 1-m patches, of habitat. This scale was adopted for the correlations for study objective 2 because adverse effects, such as areas devoid of vegetation, were identified at isolated locations. It was expected that if predictable dose-response relationships could be identified, then it would be at a scale less than the pad. Note that small-scale (i.e., plot) localized effects do not necessarily translate into ecological impacts.

High concentrations of explosives (HMX, RDX, 1,3,5-trinitrobenzene, and TNT) and cyanide were correlated with a decrease in vegetation abundance (percent cover, stem density, and biomass) and an increase in the percent of exotic species at the plot scale. See the results section of the report for information about why these particular plots dealt with chemicals as the causal agent and not gravel or cinders, soil compaction, or other physical causes.

High concentrations of metals were, in general, associated with increased vegetation abundance, especially at pad pair 58/59. Copper was associated with decreased vegetation abundance at pad pair 37/38. High concentrations of metals did not consistently cause an adverse ecological effect on vegetation at WBG.

There was a dose-response relationship between soil chemical concentrations and plant metrics. Numerical modeling of these soil chemical concentrations and plant metrics was conducted to develop plant protection levels (PPLs). PPLs are the soil concentrations below which any ecological plant effect would be below 20%. From the analysis conducted, it was concluded that the Hill model fits the nonlinear dose-response curves observed at WBG. PPLs protective of vegetation can be developed from the dose-response data for the following chemicals: copper, cyanide, 1,3,5-trinitrobenzene, and TNT.

If a site has no ecological impact, then the arithmetic mean soil concentrations (inside the pad boundaries) at that site may be used as a qualitative reference value for other sites that have similar soil, habitat, and chemical contamination.

Confidence varies from chemical to chemical with more confidence in the dose-response data from the Hill model.

The future decision to extrapolate the various types of PPLs from WBG to other sites is a risk assessment recommendation and a risk management decision.

1.0 INTRODUCTION

1.1 OVERVIEW

This report is a narrative of the rationale and background, methods, field sampling results, and weight-of-evidence analysis for soil, vegetation, and small mammals at Winklepeck Burning Grounds (WBG), Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio. The planning began in mid-1999. The actual sampling occurred from May to June 2000 (rodent sampling), June through August 2000 (vegetation sampling), and in August 2000 and May 2002 (soil sampling). The fieldwork was based on the *Sampling and Analysis Plan and Site Safety and Health Plan Addendum No. 2 for the Biological Measurements at Winklepeck Burning Grounds at Ravenna Army Ammunition Plant at Ravenna, Ohio* (SAIC 2000). Topics covered in this report include a site history, a description of the scope and objectives of the field sampling, the statistical considerations in sampling design, a description of the study sites and the sampling methods with emphasis on soil, and a presentation of the field sampling results for vegetation, small mammals, and the relationships of soil and vegetation. Finally, extrapolations of these findings from WBG to other areas of concern (AOCs) at RVAAP are advanced as plant protection levels (PPLs).

1.2 ECOLOGICAL DOCUMENTATION AND SITE HISTORY

Ecological Documentation

This report is one of a series that documents biological investigations at WBG and RVAAP. A screening-level Ecological Risk Assessment (ERA) was included as part of the Phase II Remedial Investigation (RI) Report of the WBG (USACE 2001). The ERA, designed to be conservative, evaluated the likelihood of harmful effects on plants and animals as a result of exposure to chemical constituents. Two subsequent reports, *Small Mammal Methods for Ground-Truthing of Ecological Risk at Winklepeck Burning Grounds at Ravenna Army Ammunition Plant, Ravenna, Ohio* (SAIC 1999b), and *Vegetation Methods for Ground-Truthing of Ecological Risk at Winklepeck Burning Grounds, Ravenna Army Ammunition Plant, Ravenna, Ohio* (SAIC 1999c), outlined possible methods for ground-truthing whether the potential ecological risk outlined in the RI ERA actually exists.

Ecological studies directed by the Ohio National Guard inventoried species and plant communities at RVAAP (ODNR 1993). In addition, five studies characterized ecological resources at Ravenna:

- small mammals (Carroll 1999);
- bats (Tawse 1999);
- plants (Gardner 1999);
- macroinvertebrates (Tertuliani 1999); and
- wetlands (Schalk, Tertuliani, and Darner 1999).

These studies documented healthy ecological conditions throughout RVAAP. The RVAAP WBG Phase II RI (USACE 2001) contains a discussion of ecological resources that further substantiate the healthy situation at WBG.

Site History

A detailed history of process operations and waste processes for each AOC at RVAAP is presented in the *Preliminary Assessment for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 1996). Operational history, contaminant distribution and extent, and identified contaminants of concern (COCs)

for WBG are described in detail in the previous Sampling and Analysis Plan (SAP) Addendum No. 1 for the Phase II RI (USACE 1998b) and in the Phase II RI report (USACE 2001). A brief summary of the results of the RI activities to date is presented in the following sections.

The WBG began operation in 1941 and encompasses approximately 80.9 ha (200 acres) in the central portion of RVAAP. A site map for WBG is shown on Figure 1-1. Historical operations at WBG include thermal treatment of munitions, bulk explosives and propellants, and explosives-contaminated combustible materials using open burning. In some instances, high-energy material, such as black powder, and explosives were also laid out in a string along a road and burned (USATHAMA 1978). Burning is also known to have occurred along Road D. Prior to 1980, wastes disposed by burning included hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), antimony sulfide, Composition B, lead oxide, lead thiocyanate, 2,4,6-trinitrotoluene (2,4,6-TNT), propellant, black powder, sludge and sawdust from load lines, and domestic wastes. Also, small amounts of laboratory chemicals were routinely disposed of during production periods. Shrapnel and other metallic munitions fragments were allowed to remain on-site after detonation, as were possible residual explosives. Waste oil (hydraulic oils from machines and lubrication oils from vehicles) was disposed in the northeast corner of WBG until 1973.

Prior to 1980, burning was carried out in four burn pits, on burn pads, and sometimes on the roads. The burn pits consisted of areas bermed on three sides, ranging from approximately 13.4 m (shortest side) to 26.7 m (longest side) (44 to 87 ft) depending on the burning pad. It is suspected (USACE 2000b), but not presently confirmed, that the four burn pits correspond to pads 58, 59, 60, and 61, with pit 1 corresponding to pad 58 (Figure 1-1). Of the four pits, pit 1 was used most frequently. The burn pads generally consisted of level areas without berms 6 to 12.2 m (20 to 40 ft) in width and length. It is not known how many pads were contained within the AOC. Currently, 70 burning pads have been identified from historical drawings and aerial photographs (Figure 1-2). Burning was conducted on bare ground. Ash from these areas was not collected (Jacobs Engineering 1989). Scrap metal was reclaimed and taken to the landfill north of Winklepeck (RVAAP-19).

After 1980, thermal treatment of munitions and explosives was conducted only in a 0.4-ha (1-acre) area at burning pad 37, compliant with the Resource Conservation and Recovery Act of 1976 (RCRA). Burning was conducted in metal refractory-lined trays set on top of a bed of crushed slag in an area approximately 30.5 by 30.5m (100 by 100 ft) in size. Ash residues were drummed and stored in Building 1601 on the west side of WBG pending proper disposition. The burn trays were removed from burning pad 37 in 1998, and the site was closed under RCRA.

Two additional RCRA-regulated units besides burning pad 37 are located within WBG and have either been closed or are in the process of closure (Figure 1-1). These two units are the Deactivation Furnace Area and Building 1601. Building 1601 has been certified closed. Additional sampling of surface and subsurface soils at the Deactivation Furnace and Building 1601 in support of closure activities was conducted in the fall of 1997. Closure activities for pad 37 consisted of the decontamination and removal of the burning trays; those at Building 1601 included sampling through the floor and outside the doors of Building 1601 with subsequent decontamination of the structure. To date, closure activities at the Deactivation Furnace have included removal of structures and sampling and analysis of the subsurface soils.

1.3 GRADUATION TO A FIELD-BASED APPROACH

The ERA process at WBG follows the eight-step U.S. Environmental Protection Agency (EPA) [1997] process: (1) screening-level problem formulation and ecological effects evaluation; (2) screening-level preliminary exposure estimate and risk calculation; (3) baseline risk assessment problem formulation; (4) study design and data quality; (5) field verification of sampling design; (6) site investigation and analysis of exposure and effects; (7) risk characterization; and (8) risk management. The majority of this report deals with Steps 5 and 6.

At WBG, the screening-level ERA (Step 2), using the hazard quotient (HQ) methodology, indicated a high potential for adverse ecological effects from certain contaminants [explosives, metals, and semivolatile organic compounds (SVOCs)] at some burning pads (USACE 2001). The traditional HQ approach that was used in the RI screening-level ERA compared estimated exposures (e.g., milligram contaminant/kilogram body weight/day) with screening ecotoxicity values [e.g., chronic no observed adverse effect levels (NOAELs), (EPA 1997)]. Where one or more exceedances of the conventional "threshold" HQ value of 1 is noted, the ERA could graduate to a field-truthing effort in order to determine whether unacceptable risk is truly present.

Ground-truthing methods are meant to support and to add information to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) process through field measurements and to eliminate the need for more HQ computations. The intent of these methods is to be in harmony with the latest EPA guidance (EPA 1997, 1998). Further consensus was developed through planning meetings among the U.S. Army, Ohio EPA, Science Applications International Corporation (SAIC), personnel of the RVAAP [Operations Support Command (OSC)], the Ohio National Guard, and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM).

Consistent with the EPA guidance for screening-level ERAs (EPA 1997, 1998), HQs were calculated for 70 burning pad sites during the Phase II RI for WBG (USACE 2001). Many HQs exceeded one, and the higher the HQ (e.g., 100, 1000, higher) the greater the level of concern. For example, an HQ of 2320 was associated with cadmium. The intent of HQs was to screen plant, soil invertebrate, mammal, and bird receptors of interest. For example, small mammals were identified as one susceptible receptor. Regarding chemicals, a few metals (e.g., aluminum, cadmium, lead) and a few explosives [e.g., 2,4,6-TNT, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine or high melting explosive (HMX)] were identified as being the principal sources of ecological risk. After further consideration of the background chemical concentrations in soil and weight-of-evidence for aluminum, 7 of the 70 burning pads continued to pose an ecological health concern to species that served as surrogates for a much greater list of terrestrial receptors at WBG. Thus, the screening-level ERA served its purpose of showing which receptors, which chemicals, and which pads were of highest concern. In short, the screening-level ERA pinpointed the likely problem. However, the HQ approach does have limitations.

HQs have a number of limitations in ERAs, but, first and foremost, they are not measures of risk. Risk is the probability that an event such as a toxicological effect will occur, and HQs are not probabilities (EPA 1989; Bartell 1996). The HQ is a mathematical comparison of the analyte concentration at the site to a toxicity value for that analyte. Hence, based on the HQ alone, it cannot be concluded that unacceptable risk or impacts are present. A second critical HQ limitation is that the HQ values do not represent the percentage of a population that is likely to be affected by site contaminants. Thus, an HQ of 5 does not mean that 5% of the population is expected to bear the negative health effects that arise from exposure to environmental contaminants. In recognition of HQ method limitations, EPA's ERA guidance (EPA 1997, 1998) recommends that field efforts be employed in order to verify that modeled HQs above 1 are correct in their prediction of ecological health effects at a site.

The intent of the field-truthing effort was to determine what population-relevant effects had taken place (and were still occurring) at the burning pads. Although the guidance makes this recommendation, it does not provide examples of field study designs used for accomplishing this verification task. This field-truthing effort is not intended to be iterative in design as can be the HQ method. Rather, the field-truthing effort applied at WBG was developed to identify ecological effects in the field, should these be present. A critical underlying assumption of the effort was that toxicological responses would have already occurred in plants, mammals, and other organisms at WBG as a result of historical (i.e., decades-old) exposure to site chemicals. Because ecological receptors have relatively short life spans, and many generations have persisted through the contaminated site conditions, any adverse ecological effects

would have been manifested by now. Since no new contamination is being added to the site, and, further, since natural attenuation of contaminants amenable to these processes is occurring, evaluation of future toxicological effects need not be done (i.e., the worst that can happen has already occurred).

As stated earlier, the purpose of the fieldwork reported here was to test the validity of these mathematical predictions (i.e., HQs). The screening-level ERA evaluated risks to several terrestrial receptors (plants, earthworms, short-tail shrews, American robins, cottontail rabbits, white-tailed deer, red-tailed hawks, barn owls, and red foxes) at 70 exposure units. The exposure units included the cumulative area encompassed by the burning pads, as well as the pads evaluated on an individual basis. The terrestrial screening-level ERA concluded for all of WBG that potential ecological risk (HQ >1) exists from surface soils for the entire WBG, as well as for some of the smaller pad areas. Ecological risk to one or more of the terrestrial receptors came from a variety of ecological contaminants of potential concern (COPCs). Typical inorganic COPCs included aluminum, cadmium, chromium, lead, and zinc, and the primary organic COPCs included TNT, HMX, and RDX. Regarding each individual pad, the ERA found that some pads had only a few COPCs while others had many, and some COPCs at the pads had low HQs (e.g., 5) while others had high HQs (e.g., 2000). Additionally, the following summarization was provided by the Phase II RI: “One pad (pad No. 4) has risk with HQs in the 1 to 100 range from the inorganic COPCs aluminum, arsenic, chromium, lead, selenium, and zinc. A total of 46 pads have ecological risk in the 100 to 1000 range from aluminum almost exclusively. Seven pads have ecological risk in the 100 to 1000 range from metals such as aluminum, cadmium, lead, thallium, and zinc, and explosives such as TNT, HMX, and RDX. These risks are found at pad Nos. 8, 40, 45, 61, 62, 67, and 68. Seven pads have ecological risk in the 1000 and greater range from aluminum, cadmium, and lead. These risks are found at burning pad Nos. 32, 37, 38, 58, 59, 60, and 66” (USACE 2001). Thus, the mathematical model of the food webs showed exceedances of HQs and suggested ecological danger, or a problem of some type, at some pads.

FIGURES

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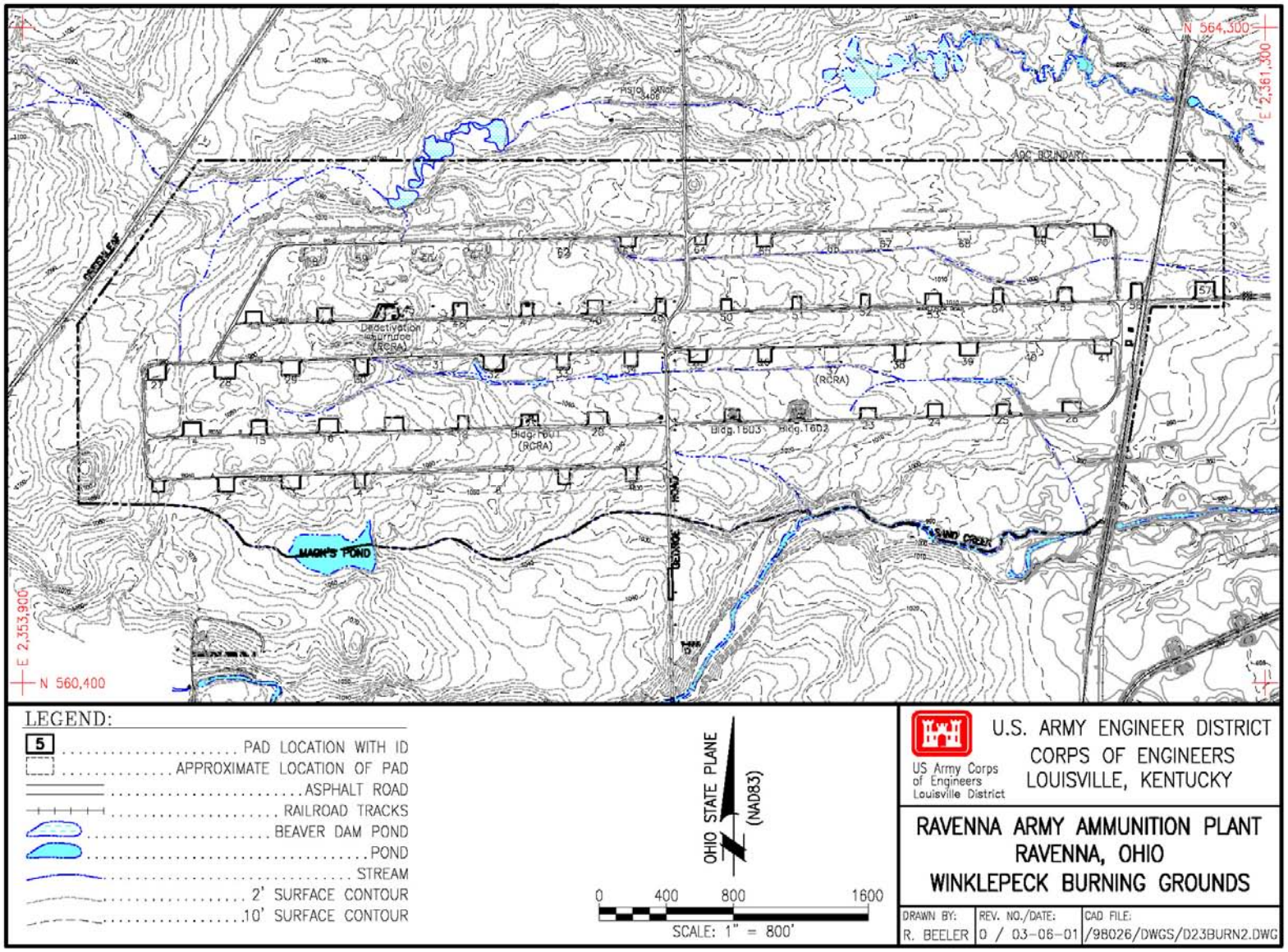

Figure 1-1. Map of Winklepeck Burning Grounds

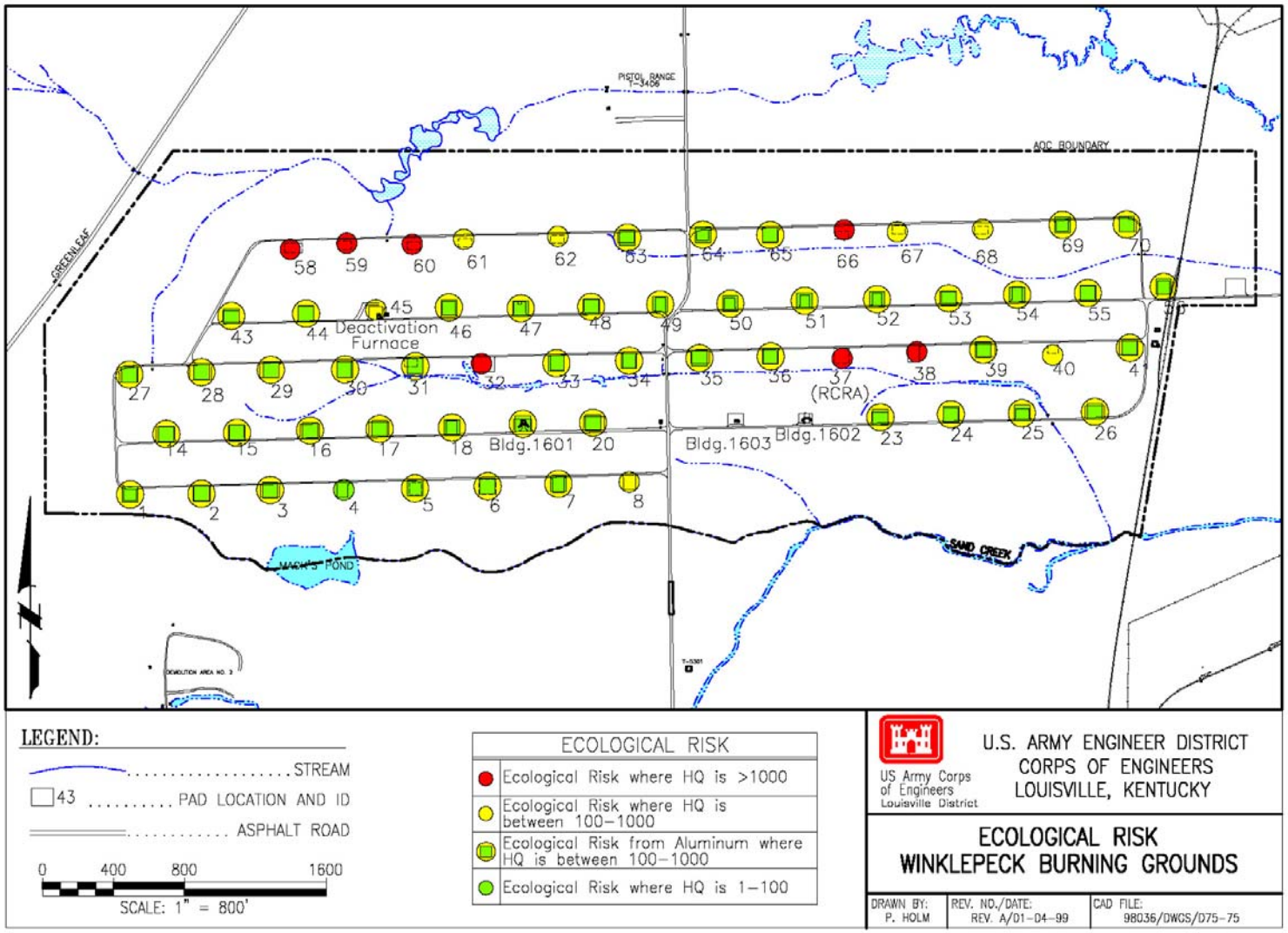

Figure 1-2. Predicted Ecological Risk at WBG

2.0 SCOPE, OBJECTIVES, AND APPROACH

The scope of this investigation was to determine whether contaminants at WBG actually produce significant effects in ecological receptors (i.e., plant communities and small mammals). In addition, the methods appropriate for measuring impacts to vegetation and to small mammals at the WBG were identified, planned, and implemented to assess their usefulness for future risk investigations at WBG and other AOCs at RVAAP and possibly at other OSC sites. To satisfy this scope two objectives were developed.

Study objective 1 was to document and compare vegetation and small mammals on burning pad sites (that were subjected to chemicals) with vegetation and small mammals at similar reference sites. Reference sites were sites whose approximate size and major hydrological, topographical, degree of maintenance (such as mowing), plant community type, and historical land use matched those of the selected burning pads. For example, with regard to vegetation sampling, the percent cover, species richness (number of species), stem density (number of stems), biomass (dry weight of all plants in a plot), and community composition at burning pad sites were compared, with strong statistical assurances, to similar vegetation attributes at the reference sites. Further, the reproductive condition and relative abundance of small mammals at burning pad sites were compared, using weight-of-evidence analysis, to similar small mammal attributes at the reference sites and to literature thresholds.

Study objective 2 was to gather field-observed data for the development of remedial goal objectives at WBG. To accomplish this, the soil concentrations were measured at selected places at the burning pads, and the chemical concentrations were related to vegetation status according to the five metrics (percent cover, species richness, biomass, stem density, and community composition). Note that the statistical rules for objective 2 were necessarily different than for the work in objective 1.

Information related to study objective 1 is presented in Chapters 3.0 through 7.0 of this report. Topics related to study objective 2 are presented in Chapters 8.0 and 9.0.

Team members representing the U.S. Army, Ohio EPA, SAIC, RVAAP (OSC), the Ohio Army National Guard, and the USACHPPM collaborated in planning and executing this field study and analyzing the data collected. Consensus among team members was reached on certain assumptions and practices in this field-truthing effort:

- HQs > 1 do not necessarily indicate an actual risk to the environment.
- Comparison between WBG pads and reference sites must account for the temporal use of the land and types of physical disturbances.
- Percent cover, species richness, stem density, biomass, and community composition, as endpoints for vegetation, are reliable and appropriate measures of impact at WBG (SAIC 1999c; USACE 2000).
- A cause-effect relationship of chemical contamination in soil to vegetation impacts can be identified if it exists.
- Reproductive effects as endpoints for small mammals were assumed to be useful measures of biological impact at WBG.

- Small mammal sampling would precede vegetation and soil sampling because vegetation clipping and soil augering would disturb the mammals and their habitat.

- Protection of vegetation and small mammals can translate into protecting other ecological receptors.

Vegetation was sampled at selected burning pad sites at WBG and reference sites outside WBG, but within RVAAP, to quantify vegetative cover, productivity, and measures of community composition. Specifically, percent cover, species richness, stem density, and biomass were measured, and community composition was computed. The uncontaminated reference sites, selected to mirror contaminated site conditions and disturbance history of burning pad sites, served as comparisons for vegetation on the burning pad sites. The hypothesis was tested that vegetation in a particular burning pad site does not differ from vegetation in the reference site selected for comparison with that pad. Differences in vegetative characteristics between the burning pad sites and reference sites were assumed to be attributable to the presence of chemical contaminants in the soils. In conjunction with a subset of the vegetation samples, surface soil samples were collected from collocated sites at the same burning pad sites.

Small mammals were used to assess the potential impact of chemicals in soils at WBG burning pads. This was done by comparing sperm parameters (i.e., sperm counts, sperm motility, and sperm morphology) from contaminated sites (i.e., burning pad sites at WBG) and reference sites (i.e., outside WBG but within RVAAP). Reproduction is the key toxicological endpoint, and, thus, field investigations focused on reproduction. Small mammals constitute a significant portion of the wildlife at RVAAP as demonstrated by the Ohio National Guard inventories mentioned in Section 1.2. Species composition (i.e., species identification and sex and age determination) was also assessed at contaminated and reference sites. In addition to constituting a significant portion of the wildlife at the installation and being easy to capture, small rodents are recognized as terrestrial receptors with a maximal degree of vulnerability to the soils due to their limited home range and habitats.

3.0 STATISTICAL DESIGN

3.1 RATIONALE

The natural world of vegetation and animals varies from year to year and from place to place. Yet, these populations and communities of organisms have attributes that can be measured. At RVAAP, the quest to determine what attributes to measure began with the planning meetings and two methods documents (SAIC 1999b, 1999c). Statistical design, powerful enough to measure and analyze attributes of biological populations, was a key part of that planning.

Measurements of an attribute of any population (or system) have inherent certainties and uncertainties. Uncertainties exist because of natural or inherent spatial and temporal variability of the attribute and because the measurement process assesses only a subset of the entire population. In this study statistics are used to determine if the observed differences between samples of populations are significant (i.e., are the differences larger than the uncertainties associated with them) and to determine the strength of the correlations between soil chemistry and ecological attributes. Statistics provide a quantitative framework for assessing the uncertainty and estimating the probability that the measured condition represents the actual condition of the population. Statistics can also help determine how much information is required to give reasonable confidence in the result of a statistical test.

3.2 STATISTICAL TESTS

Several statistical tests are used in this study to help make decisions about the data. The Wilcoxon rank sum test is used to compare two groups of samples to determine if the populations sampled are significantly different from each other. The Shapiro-Wilk test is used to determine if a group of measurements has a normal distribution. The Spearman rank correlation tests whether two different measures on the same sample tend to vary in the same or opposite direction within the group.

3.2.1 Wilcoxon Rank Sum Test

The Wilcoxon rank sum test uses the relative ranks of the measurements from two different groups of data to determine if the values in one group are significantly higher or lower than the other group. This test is a non-parametric test because it does not rely on the assumption that the distributions of the measurements are normal. This non-parametric test was chosen for this study with the expectation that some of the distributions examined would not be normal. An advantage of using the Wilcoxon rank sum test is that when the data distributions examined are normal, the test is nearly as powerful at detecting differences in samples as the parametric Student “t” test, and when the distributions are not normal, the test probabilities are more accurate than the t-test (Gilbert and Simpson 1992).

The sum of ranks for the measured characteristic from the contaminated site is computed and compared to a table to determine the probability that the contaminated and reference sites could be as different as was observed if the samples had actually come from the same site. If the probability is very small (less than the alpha level), the sites are considered significantly different from each other with respect to that characteristic.

For this study the NPAR1WAY procedure that is part of the SAS statistical software (SAS 1999) was used to calculate the probabilities associated with the Wilcoxon rank sum test. The probabilities can be determined assuming a “one-tailed” test or a “two-tailed” test. A one-tailed test looks for a significant difference only if it occurs in the expected direction. For example, if biomass is expected to be greater on

the reference site than the contaminated site, a one-tailed test might be performed. The test would indicate a significant difference if the results from the reference site were larger than the contaminated site. The test would not tell, however, if the results from the contaminated site were significantly larger than the reference site. While there are expectations for the direction of differences between the reference and contaminated sites, there is interest in detecting differences in either direction. For example, contaminants could inhibit or stimulate plant growth. Therefore, the two-tailed probabilities for the Wilcoxon rank sum test are reported here. The probability for the one-tailed test would be one-half the probability reported for the two-tailed test.

3.2.2 Shapiro-Wilk Test

Repeated measurements of any environmental attribute of any system will vary as a result of differences in that attribute from individual to individual, from place to place, from time to time, as well as from errors in the measurement. The measurement of an attribute, therefore, results in a "population" of measurements rather than a single value. If the shape of the frequency distribution of that population of measurements can be described by a specific symmetrical bell-shaped curve, then the distribution is considered to have a "normal" probability distribution. Many statistical tests are based on the assumption that the probability distribution of the measurements being tested is normal. These statistical tests are called "parametric" tests. If the distribution is not normal, then the probabilities used to determine the significance of the parametric test results are not exact.

The probability distribution of the attribute being measured is not usually known. The Shapiro-Wilk test compares the distribution of measurements taken to a theoretical normal distribution and determines the probability that the measurements taken could have come from an underlying normal distribution. The test cannot prove that a distribution is normal, but it can determine if the measured distribution is significantly different from normal. For this study, the Shapiro-Wilk test was performed using the UNIVARIATE procedure of the SAS software system (SAS 1999). If the probability for the Shapiro-Wilk test was less than the selected alpha level, then the distribution was considered different from normal. If the probability was greater than or equal to the selected alpha level, then the distribution was considered not different from normal.

3.2.3 Spearman Rank Correlation

Correlation tests are used to quantify how closely changes in one variable are associated with changes in another variable. The choice was made to test for correlations between variables using the Spearman rank correlation test so the relationships that exist between variables would be known.

The Spearman rank correlation test converts all measurements to ranks and then tests for linear correlations between the ranks. The use of rank correlation will detect any relation where one variable generally increases or generally decreases with increases in the other variable. Rank correlation can detect linear relationships (where one variable changes in direct proportion to the other) as well as logarithmic relationships (where one variable changes in proportion to a power of the other variable). Outlier measurements (measurements that are much larger or much smaller than the majority of the measurements) have less effect on a rank correlation than they would on a linear correlation.

The SAS REG procedure with the SPEARMAN option (SAS 1999) was used to calculate the correlation statistics for this study. Two statistics were calculated for each correlation: the correlation coefficient and the probability associated with the correlation coefficient.

The correlation coefficient is a measure of the direction and closeness of the correlation. The absolute value of the correlation coefficient varies from zero to one. A correlation coefficient of zero indicates no

correlation between the variables. A correlation coefficient of one indicates a perfect correlation—an increase in one variable is always accompanied by a change in one direction in the other variable. The sign of the correlation coefficient indicates the direction of the correlation. A positive correlation coefficient means that an increase in one variable is associated with an increase in the other variable. A negative correlation means that an increase in one variable is associated with a decrease in the other variable.

The probability associated with the correlation coefficient is the probability that a correlation as high as that observed could have occurred from chance alone if the variables were actually uncorrelated. This probability allows the assessment of the significance of the correlation coefficient. For this study, only correlations with probabilities less than selected alpha level were considered significant. The relationship between the correlation coefficient and the probability varies with the number of measurements. The more measurements, the smaller the absolute value of the correlation coefficient that would be considered significant.

3.3 SELECTION OF STATISTICAL CRITERIA

The primary objective of this study was to determine if the ecological attributes at the WBG sites were different from the attributes at the matched reference sites. This objective was expressed as a null hypothesis for each attribute and site: i.e., the population attribute at the WBG site is not different from the attribute at the reference site. The Wilcoxon rank sum test was chosen for testing this hypothesis. This section describes the selection of statistical criteria required to assess the confidence that may be placed in the results of the statistical test.

The selection of statistical criteria is an expression of the data quality objectives of the study. The RVAAP project team developed these objectives over a series of workshops and conference calls. The criteria selected represent a consensus of the team's expert judgments and opinions. The statistical criteria were selected considering the consequences of incorrectly rejecting the null hypothesis when it was true and incorrectly accepting it when it was false. The statistical criteria selected by the project team were: alpha level, power, and significant difference.

The **alpha (α) level** of a test is the probability that the test result would indicate that the populations were different; when in reality they were not different. The α level of a test is chosen based on the consequences of making an incorrect decision that the populations are different when they are not. Since the evaluator does not want to make an incorrect decision, a low α level is selected. An α level of 0.05 is commonly used. This means that there is only a 5% chance that the test will say that the populations are different when they are not. In the case of environmental tests to determine if an area is contaminated relative to a reference site, a higher α level may be accepted because the consequence of calling the populations different, when they are not, would tend to be over-protective (rather than under-protective) of ecological resources. The consequence would be to remediate an area that did not need to be remediated. The advantage of a higher α level is that fewer samples would be required to achieve the same power than at a lower α level. The team considered a range of alpha from 1% to 20%. The team decided that it was important to keep this type of error small and, therefore, chose an alpha level of 5%.

The **power** of the test is the probability that a difference would be detected by the test if there really were a difference. The power of a test is chosen based on the consequences of making an incorrect decision that the populations are the same when they are actually different. The power does not generally receive as much attention as α level because hypotheses are usually posed so that the consequences of not finding a difference, if there were one, would not be significant. Also, the power can only be assessed if the amount of difference that would be considered significant is known and if the variability of the measurements is known. This information may not be available before a test is conducted.

For this study, the consequence of not rejecting the null hypothesis when it is false results in the conclusion that there is no ecological effect of contamination when there actually is an effect. The team decided that it was important to keep the probability of this type of error low. After considering a range of power from 80 to 99%, the team chose 95% as the power criteria. At a power of 95% the chance of the statistical test finding no difference, when there actually is a difference, is 5%.

In order to calculate the power, the team had to decide how large a difference in the ecological attributes would be considered a **significant difference** in terms of its ecological impact. The team considered a range of differences from 20 to 50%. The team chose 20% as the difference in the ecological attributes that should be detectable with 95% power at an alpha level of 5%.

The biological **sample size** had to be determined before field measurements could begin. The sample size is the number of measurements of the attribute of the population. The sample size was dependent on the statistical criteria selected by the team (alpha level of 5%, power of 95%, and significant difference of 20%) as well as the expected variability of the measurements. In general, greater numbers of samples allow greater capability to detect significant differences between groups if they exist. However, more samples involve greater time, effort, and cost in order to show, with a high degree of statistical reliance, that the measured attributes are not really different.

Variability is the spread of values observed when taking repeated measures of the same attribute from the same population. The variability is discussed here in terms of the coefficient of variation. The **coefficient of variation (CV)** as a percent is 100 times the standard deviation divided by the average. The variability of the measured attribute affects the sample size required to observe a specified significant difference at a specified power and α level. The greater the variability, the larger the number of samples required to detect a specified difference.

To estimate the number of biological samples needed, the CV was estimated based on studies from the literature and previous studies at RVAAP. Expected CV values varied from attribute to attribute and may vary from 10 to 130%. Given the selected Wilcoxon rank sum test and assuming that the data are normally distributed, the sample size may be calculated. For the 5% α level, 95% power, and 20% significant difference selected, the range in CV corresponded to a sample size ranging from 21 to 1924 samples. Overestimating the CV could result in taking more samples than needed and, therefore, wasting time, effort, and money. Underestimating the CV, on the other hand, could result in not having enough samples to make a decision with the desired confidence and, therefore, needing to go back to the field and take additional samples. Re-sampling would cost additional time, effort, and money.

This dilemma was approached by selecting the sample size based on the ratio of the significant difference to the CV, rather than assuming a specific CV. The ratio of the significant difference to the CV may be thought of as a signal-to-noise ratio. The significant difference is the signal, and the CV is the noise. The smaller the noise, the smaller the signal that can be detected. The less variable an attribute (the lower the CV), the smaller the difference that one would expect to be able to detect. Selecting a significant difference to CV ratio, rather than CV independently, and assuming a normal distribution, one can determine the sample size without having to estimate the CV (Table 3-1).

The significant difference/CV ratio of 1.0 was chosen to determine the number of samples needed to test for differences between the WBG and reference sites. Setting the significant difference/CV ratio to 1.0 means that the sample size should be sufficient to detect a significant difference as large as the standard deviation. If the measured CV is 20% or less, the team will have met its original goal for detecting a 20% difference. If, however, the measured CV is greater than 20%, the team's original goal will not be met.

The choice of a ratio of 1.0 for the significant difference/CV ratio can be related statistically to the range of the measured values of the ecological measurements. If the distribution of measurements can be considered statistically normal, the range of the measurements (maximum – minimum) is about five times the standard deviation. This means that the CV is about 20% of the range. Thus, with a significant difference/CV ratio of one, the detectable significant difference would be about 20% of the range.

Thus, the choice of significant difference/CV ratio of one had a statistical basis that can relate the size of the detectable significant difference to the range of the ecological measurement. The choice of the ratio allowed us to choose a sample size without knowing the variability that we would find in the field measurements. This is visualized in Figure 3-1.

Given the specified alpha level of 5%, power of 95%, and significant difference/CV ratio of 1.0, 54 samples were required for each test, 27 from each WBG site and 27 from each reference site. This selection of sample size was based on the Wilcoxon rank sum test. The Wilcoxon rank sum test is a non-parametric test for differences between the values of two sample populations. The Wilcoxon test was chosen because it is nearly as powerful as parametric tests and may be used when the distribution of attribute values is not normal.

While the Wilcoxon rank sum test is non-parametric, an assumption must be made about the statistical distribution of the measurements in order to calculate the sample size for a specified alpha level, power, and significant difference/CV ratio. The sample sizes presented in Table 3-1 are based on calculations that assume that the underlying distribution is normal. It should be recognized that if the underlying distribution is not normal, the values in Table 3-1 represent estimated rather than actual values.

Based on the specified statistical criteria, a sample size of 27 from each WBG study site and from each reference site (54 divided by 2) would provide sufficient data for testing differences between plots. To allow for the possibility of lost data, the sample size was increased by 10%. Therefore, the aim was to take at least 30 samples at each study site and reference site. Chapter 4.0 describes these study sites and reference sites.

3.4 SUMMARY

In summary, for study objective 1, a 5% alpha level, 95% power, and a ratio of significant difference/CV of 1.0 results in 54 samples required (Table 3-1), or 27 at each pad and reference location, plus a 10% increase in sample size for contingencies. (See Chapter 4.0 for a description of pad and reference locations.) Therefore, 30 vegetation and 30 small mammal samples were required from each of the 3 reference sites and each of the 3 WBG sites to detect a significant difference greater than or equal to the CV. Differences that are not statistically significant would be considered definitive evidence of no ecological effect when measured CV values were less than or equal to 20%, the detectable significant difference specified by the study team. For attributes that are not statistically different, but have CVs greater than 20%, the statistical results will be one of several lines of evidence used to discuss the ecological significance of the measured attributes.

For study objective 2, quantifying the relationship between soil chemistry and ecological attributes, additional biased samples were selected as described in Chapter 4.0. Spearman rank correlations were used to assess the strength of the relationships as described in Chapter 8.0.

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FIGURES

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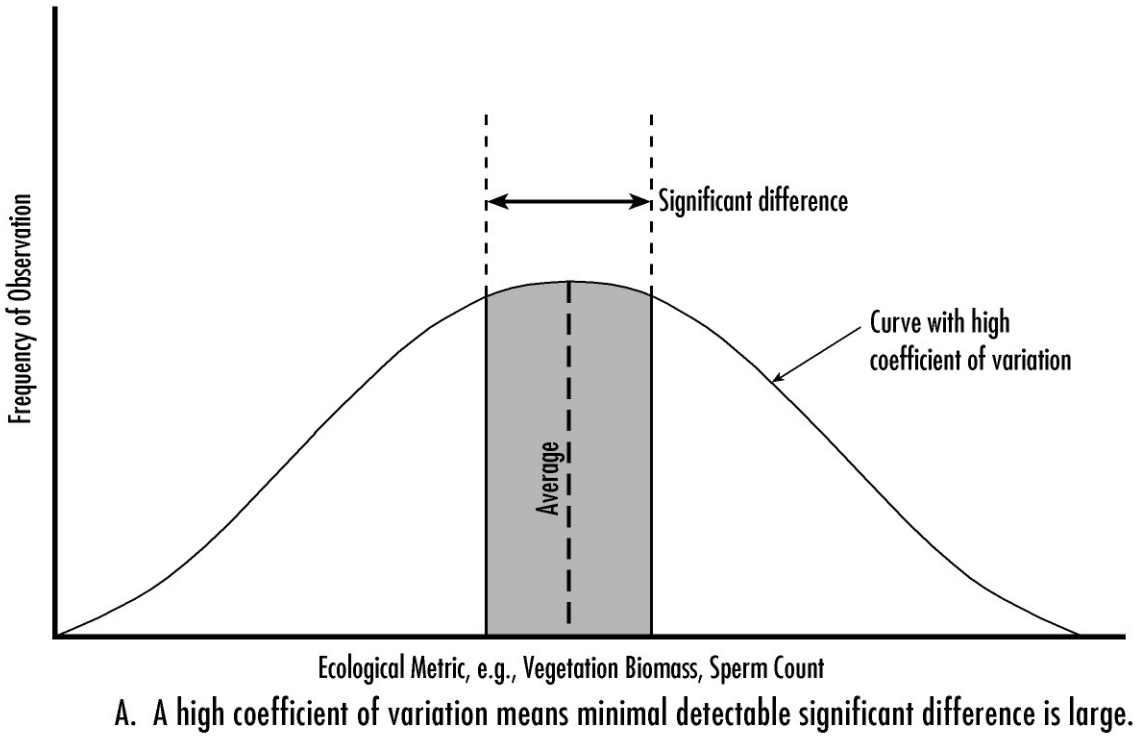
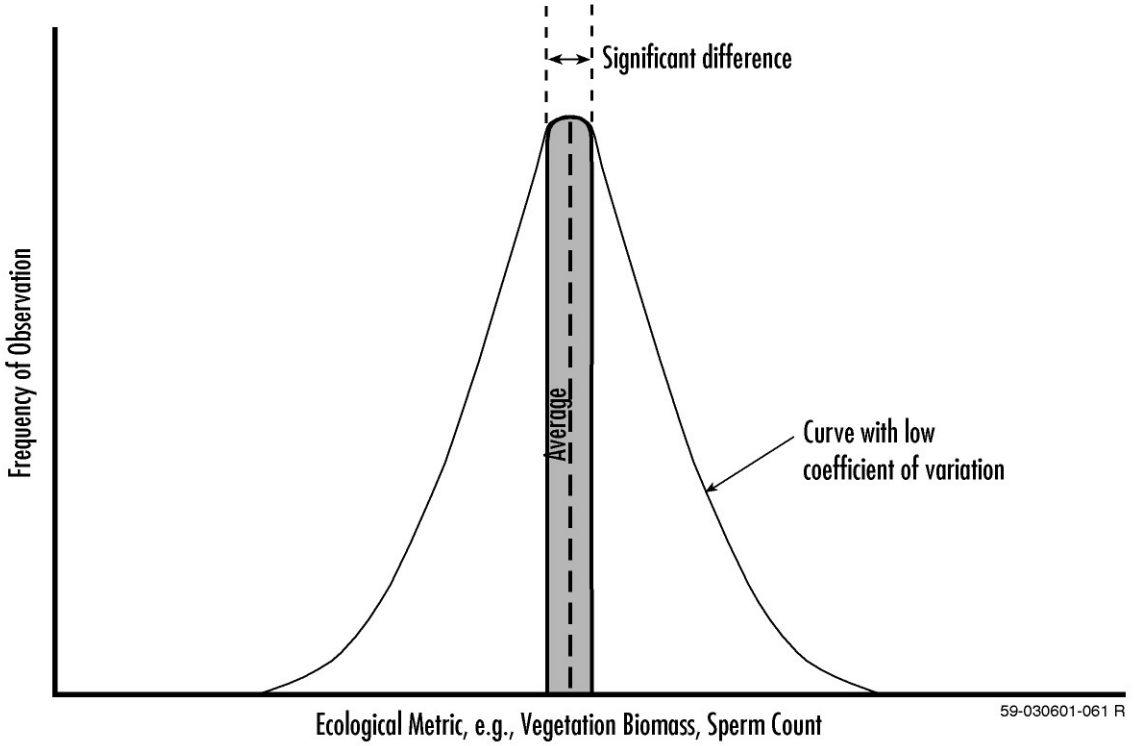


A. A high coefficient of variation means minimal detectable significant difference is large.



B. A low coefficient of variation means minimal detectable significant difference is small.

Figure 3-1. Visualization of Significant Difference to Coefficient of Variation Ratio of 1

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TABLES

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Table 3-1. Number of Samples Required to Obtain Specified Alpha Level and Power for a Specified Percent Difference and Coefficient of Variation when Measurements are Normally Distributed

	Total Number of Samples Required						
	Power %					Diff%/	Max CV for 20%
Alpha %	80	85	90	95	99	CV%	Diff.
1	19	22	25	30	41	2	10
5	12	14	17	21	30	2	10
10	9	11	13	17	25	2	10
15	7	9	11	14	22	2	10
20	6	7	9	12	19	2	10
Alpha %	**80**	**85**	**90**	**95**	**99**		
1	27	30	35	42	58	1.5	13.3
5	17	19	23	29	42	1.5	13.3
10	12	15	18	23	35	1.5	13.3
15	10	12	15	19	30	1.5	13.3
20	8	10	12	17	27	1.5	13.3
Alpha %	**80**	**85**	**90**	**95**	**99**		
1	50	56	65	78	107	1	20
5	31	36	43	54	78	1	20
10	23	27	33	43	65	1	20
15	18	22	27	36	56	1	20
20	14	18	23	31	50	1	20
Alpha %	**80**	**85**	**90**	**95**	**99**		
1	82	93	107	129	177	0.75	26.7
5	51	59	70	89	129	0.75	26.7
10	37	44	54	70	107	0.75	26.7
15	29	36	44	59	93	0.75	26.7
20	24	29	37	51	82	0.75	26.7
Alpha %	**80**	**85**	**90**	**95**	**99**		
1	176	198	228	276	379	0.5	40
5	108	126	150	190	276	0.5	40
10	79	94	115	150	228	0.5	40
15	62	76	94	126	198	0.5	40
20	50	62	79	108	176	0.5	40
Alpha %	**80**	**85**	**90**	**95**	**99**		
1	680	767	882	1069	1467	0.25	80
5	419	488	581	734	1069	0.25	80
10	306	364	446	581	882	0.25	80
15	239	292	364	488	767	0.25	80
20	192	239	306	419	680	0.25	80

[a]Sample size selected to provide sufficient data for testing differences between burning pad sites and reference areas.
CV = coefficient of variation.

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4.0 STUDY SITES AND SOILS

4.1 OVERVIEW

Six study sites (three paired burning pad sites and three paired reference sites) were included in the May through August 2000 sampling events. The soils at the reference sites were sampled in May 2002. The May 2002 sampling was designed to document chemical concentrations in soils at the reference areas to better establish their suitability for use as comparison sites to WBG pads.

The characteristics of burning pad sites, including soil chemistry, are described in Section 4.2; reference sites are described in Section 4.3. Details about the selection process for the reference sites are found in Addendum 1 of SAIC 2001. In addition, the locations of the soil samples and the vegetation sampling grids are illustrated relative to the locations and sizes of the burning pad sites in order to show the presence of contamination at the WBG sites.

4.2 BURNING PAD SITES

4.2.1 Selection of Burning Pads

The three pairs of burning pads selected for the field-truthing effort at WBG are pads 37 and 38, pads 58 and 59, and pads 66 and 67. Pairs of burning pads were used to provide a large enough area for a range of vegetation conditions and for small mammal home ranges. These pads are primarily vegetated by grasses and forbs, and a few have barren areas [i.e., some with slag over soil and some with bare soil (burning pad 67)] of varying size scattered within the vegetation community. These three pairs of adjacent burning pads exhibited high ecological HQs for metals, SVOCs, and/or explosives in the screening-level ERA (USACE 2001). The screening-level ERA concluded that seven burning pads (32, 37, 38, 58, 59, 66, and 67) demonstrated potential for ecological risk (HQ > 1000) from aluminum, cadmium, and lead (USACE 2001). Pad 32 had no geographically proximate companion to complete the statistical design of the pairing approach and was dropped. Pads 37 and 38 demonstrated potential for ecological risk (HQ between 100 and 1000) from aluminum where historical slag application up to 30 cm (12 in.) thick was evident. Pads 58 and 59 demonstrated the highest potential for ecological risk (HQ > 1000) from aluminum, cadmium, and lead, and pads 66 and 67 demonstrated a high potential for ecological risk (HQ between 100 and 1000) from metals and explosives (TNT, RDX, and HMX). Because these three pairs of burning pads indicated the highest potential risk, it was assumed they provided the most likely places for ecological effects to have occurred and the best chance to ensure success for the field-truthing effort. In addition, the paired burning pads were reasonably well separated from one another, improving the effectiveness for mammal sampling and reducing the confounding due to exposure to multiple sites of contamination.

4.2.2 Previous Soil Sampling

Four different soil sampling efforts were conducted to support the RI/Feasibility Study (FS) reports. The first was conducted in July and August 1996 and is described in *Phase I Remedial Investigation Report for 11 High-Priority Areas of Concern of Ravenna Army Ammunition Plant, Ravenna, Ohio* (SAIC 1998). The second soil sampling, which occurred in April and May 1998 as part of the Phase II investigation, is documented in *Phase II Remedial Investigation Report for the Winklepeck Burning Grounds at the Ravenna Army Ammunition Plant, Ravenna, Ohio* (SAIC 1999a). Phase III soil samples were taken in October and November 2000 and used in this study; see Appendix F.4 for these data that have also been published in USACE, 2005. Because of the interest in Phase III data relative to the biological ground-truthing work, the sampling locations are included in the figures illustrating all four sets of soil samples along with the vegetation sampling grids (see Section 4.2.7). The fourth set of soil samples was obtained in August 2000 as part of this study, and data are presented in this

document. The sampling methodology is outlined in *Sampling and Analysis Plan and Site Safety and Health Plan Addendum No. 2 for the Biological Measurements at Winklepeck Burning Grounds at Ravenna Army Ammunition Plant at Ravenna, Ohio* (SAIC 2000). Phase III soil sampling locations are shown even though the Phase III soil samples were taken later than the biological field-truthing samples.

4.2.3 Sampling Grids

Characterization of the burning pad and reference sites was accomplished by sampling 1- by 1-m plots in a defined sampling grid at each site. A sampling grid was defined as a 15- by 20-m (49- by 66-ft) area with corner pins. Increment lines were staked every 5 m (16 ft) with wooden 2.5- by 5-cm (1- by 2-in.) stakes, and wire lines were placed in each direction. Each 5- by 5-m (16- by 16-ft) subarea contained 25 plots. All plots were assigned a unique identification number based on location within the grid (Figure 4-1).

Specific plots at WBG can be located within the 20- by 15-m grid at each site by knowing at which corner of the grid Plot 1 is found. For burning pads 37, 38, 59, and 66, and reference sites J1, J2, S1, and S2, Plot 1 is located in the southeast (SE) corner of the 20- by 15-m grid. For sites 67, E1, and E2, Plot 1 is in the northeast (NE) corner of the grid. At pad 58, Plot 1 is in the northwest (NW) corner of the grid.

The grid was chosen to be approximately the size of the typical disturbed areas at the burning pad sites. The grids were positioned at the burning pads so that they would include the graded, disturbed area of each pad.

At each site, 30 plots were randomly selected within the sampling grid for vegetation sampling as described in Chapter 6.0 of this report. For the purpose of study objective 2, additional biased sampling plots were selected within the grid so that there would be at least three plots in each of three ranges of vegetation cover (bare to sparse, medium, and high) at each burning pad site. These nine plots that covered a range of vegetation cover were also sampled for soil chemistry characterization.

4.2.4 Field Sampling Methods

This section describes the methods for soil sampling during the biological field-truthing effort and describes the soil chemistry at the three pad pairs using the data from this sampling event.

The 30 plots for paired burning pads were selected randomly for vegetation sampling. Within that set, the plots for soil sampling were selected on a biased basis as follows. Plots were selected to represent a range of vegetative cover (“selected-cover” plots). Three of these were located in each of the three following categories: (1) bare-to-sparse cover (0 to 29%), (2) scattered medium cover (30 to 69%), and (3) high cover (70 to 100%) [Figure 4-2]. Surface soil samples were taken in the selected-cover plots following harvesting of plants for biomass measurements (Figure 4-2).

From each set of 30 vegetation sample plots, 9 were selected to represent varying levels of percent cover (for study objective 2). The 30 randomly selected samples from each pair of sample sites, from which the 9 stratified selected-cover samples were selected, were insufficient to contain an adequate number of bare-to-sparse (0 to 29%) and scattered medium (30 to 69%) cover plots. Sparse and medium selected-cover plots were, therefore, identified and selected by visual inspection of neighboring plots. Between none and three of the original 30 plots were replaced by the visually identified bare-to-sparse or medium-cover plots. If more than three plots were located outside of the randomly chosen plots, the additional plots were added to, rather than substituted for, the randomly chosen plots. For this reason, there were more than 30 samples per study site. Table 4-1 shows the collocated soil samples, as well as the percent cover and randomized selection process of those soil sample locations. Figures 4-3 through 4-14 show the locations of the soil and vegetation sampling plots relative to the grids and pads.

Surface soil samples were collected with a stainless-steel bucket auger approximately 15.2 cm (6 in.) in length and 7.6 cm (3 in.) in diameter. Composite soil samples were created from three subsamples in each plot collected in a roughly equilateral triangle pattern with the subsamples positioned about 0.9 m (3 ft) apart from each other (Figure 4-2). At each subsample point, the auger was advanced in small intervals to a total depth of 30.5 cm (1 ft). Soil from each subsample was added to stainless steel bowls and thoroughly homogenized. Once the samples were homogenized, a composite sample was prepared and sent for laboratory analysis for explosives. A similar collection technique was used to obtain a discreet sample from the center of the triangular plot for metals, cyanide, and SVOCs.

The sample matrix types, analytical parameters, and analytical methods are summarized in Table 4-2, "Sampling and Analytical Requirements," in conjunction with sample numbers, quality assurance (QA) sample frequencies, and field quality control (QC) sample frequencies. Laboratory chain-of-custody followed handling and custody procedures. Sample packaging and shipping and management of investigation-derived waste (IDW) followed requirements outlined in the SAP Addendum (SAIC 2000).

4.2.5 Analytical Methods

Analytical support for the surface soil sampling activity was assigned to Severn Trent Laboratories (STL), formerly Quanterra Environmental Services, Inc. The majority of analyses were completed by STL's North Canton, Ohio, facility, with explosive determinations being performed by the Knoxville, Tennessee, facility. Each of these laboratories has been validated by the U.S. Army Corps of Engineers (USACE) as an approved laboratory. STL has also been approved by the Louisville District Environmental Chemist to follow additional Louisville District analytical protocols. In addition, QA samples were provided to GPL Laboratories in Gaithersburg, Maryland, to assist in validating and ensuring the accuracy of the analytical results. Analytical data have been independently validated by Lee Knuppel and Associates. Also, a Chemical Data Assurance Report has been prepared by Lee Knuppel and Associates (2001) and has been approved by the Louisville District Project Chemist.

STL's Quality Assurance Management Plan (QMP), Section 8.0, and the facility-specific addenda for the North Canton and Knoxville facilities were followed during the analysis of these samples. Laboratory standard operating procedures (SOPs) were implemented using EPA Methods (Table 4-2):

Table 4-2 lists the numbers and types of soil and water samples for each analytical test. In addition, there was a full suite of Toxicity Characteristic Leaching Procedure (TCLP) tests for the IDW soil and water.

4.2.6 Results for WBG Soil Sites

The concentrations of metals, cyanide, explosives, and SVOCs were determined for each of the soil samples. Data for individual soil measurements are found in Appendix F (SAIC 2001). SAIC 2001 [Appendix G] shows the relationship between soil sample identifications and vegetation sample plots and burning pads. The statistical analyses performed included only chemical results from the primary discreet or composite soil sample from each plot. The results from field duplicate and split samples were used for quality control purposes only.

Tables 4-3 through 4-5 summarize the soil concentrations of analytes detected in collocated soil samples at WBG. They include average concentration by analyte, facility-wide background criteria for inorganic constituents, number of detects greater than the RVAAP facility-wide background criteria, and the number of results above the detection limit. The tables subdivide the soil concentration data by pad pairs. Table 4-3 shows the soil concentrations at pads 37/38, Table 4-4 shows those for pads 58/59, and Table 4-5 shows the data for pads 66/67.

Pads 37/38. All of the target analyte metals were detected except for silver. Of the metals detected, most had at least one result that exceeded the facility-wide background except for manganese and vanadium. Of those inorganic constituents that did not have background values for comparison, cadmium and cyanide were detected at concentrations that exceeded the detection limits achieved in the background study while the detections of thallium were below the detection limit achieved in the background study. The comparison to the detection limit indicates that the concentrations of cadmium and cyanide may have been elevated relative to background while the thallium concentrations were too close to the detection limit to resolve. The background comparisons indicate that metals were present at pads 37/38 at concentrations that exceeded those expected under background conditions.

The explosives 1,3,5-trinitrobenzene (1,3,5-TNB), 1,3-dinitrobenzene (1,3-DNB), 2,4,6-TNT, 2,4-dinitrotoluene (2,4-DNT), 4-nitrotoluene, HMX, and RDX were detected at pad 37/38. The explosive 2,4,6-TNT was detected most frequently (6 out of 9 times) and at the highest concentration (580 mg/kg). The explosives 2,4-dinitrotoluene and 2,6-dinitrotoluene were also detected by the method for analysis of semivolatile organics along with 2-methylnaphthalene, di-n-butyl phthalate, N-nitrosodiphenylamine, and phenanthrene. Explosives were not detected at any of the background locations. The presence of explosives at pads 37/38 confirmed that this site was contaminated by munitions burning at WBG.

Pads 58/59. All of the target analyte metals were detected. Cyanide was not detected. Most metals, except arsenic, beryllium, manganese and vanadium, had at least one result that exceeded the facility-wide background. Of those inorganic constituents that did not have background values for comparison, cadmium and silver were detected at concentrations that exceeded the detection limits achieved in the background study while the detections of thallium were below the detection limit achieved in the background study. The comparison to the detection limit indicates that the concentrations of cadmium and silver may have been elevated relative to background while the thallium concentrations were too close to the detection limit to resolve. The background comparisons indicate that metals were present at pads 58/59 at concentrations that exceeded those expected under background conditions.

The explosives 2,4,6-TNT and RDX were detected at pads 58/59. The explosive RDX was detected most frequently (2 out of 9 times) and at the highest concentration (0.66 mg/kg). Explosives were not detected at any of the background locations. The presence of explosives at pads 58/59 confirmed that this site was contaminated by munitions burning at WBG. The other organics detected at pads 58/59 [2-methylnaphthalene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenzofuran, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene] were primarily polycyclic aromatic hydrocarbons (PAHs). PAHs are common contaminants that are related to combustion products.

Pads 66/67. All of the target analyte inorganics were detected including cyanide. Most metals had at least one result that exceeded the facility-wide background except for aluminum, beryllium, calcium, cobalt, manganese, nickel, and vanadium. Of those inorganic constituents that did not have background values for comparison, cadmium was detected at concentrations that exceeded the detection limits achieved in the background study while the detections of silver and thallium were below the detection limit achieved in the background study. The comparison to the detection limit indicates that the concentrations of cadmium may have been elevated relative to background while the thallium and silver concentrations were too close to the detection limit to resolve. The background comparisons indicate that metals were present at pads 66/67 at concentrations that exceeded those expected under background conditions.

The explosives 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-dinitrotoluene, 4-nitrotoluene, HMX, and RDX were detected at pads 66/67. The explosives 2,4,6-TNT, HMX, and RDX were detected in all nine of the samples analyzed. RDX was detected at the highest concentration (2400 mg/kg). Explosive were detected more frequently and at higher concentrations in the collocated samples from pads 66/67 than at the other

pads studied. Explosives were not detected at any of the background locations. The presence of explosives at pads 66/67 confirmed that this site was contaminated by munitions burning at WBG.

The SVOCs detected at pads 66/67 included: 2,4-dinitrotoluene, 2-methylnaphthalene, acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, carbazole, chrysene, dibenz(a,h)anthracene, dibenzofuran, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. Most of these chemicals are PAHs. PAHs are common contaminants related to combustion products.

4.2.7 Geographic Distribution of Soil Concentrations

Table 4-6 summarizes the numbers of soil samples taken at pad pairs 37/38, 58/59, and 66/67 throughout the phases of the RI and during the biological field-truthing. The table indicates how many samples were taken inside the boundaries of the vegetation sampling grid at each pad and how many were collected outside the boundaries of the grid. Vegetation grids were established to be within the apparent burning pad boundaries established from aerial photographs and used in the Phase I and II RIs. Subsequent mapping of vegetation grids showed some to be partially outside the pad boundaries that had been estimated from aerial photographs. Global Positioning System (GPS) surveys in April 2002 of apparent pad boundaries of pads 37 and 38 show the vegetation grids to be entirely within the pad boundaries. Thus, pad boundaries as depicted on the original base maps in the Phase I and II RIs should be understood to be approximate. Figures 4-3 through 4-14 illustrate the phases and locations of each soil sample, as well as showing the relationship of each vegetation sampling grid to its burning pad site.

Burning pads 37 and 38 are located toward the center of WBG, as shown in Figure 1-1. Pad 37 is approximately 87.5 ft (26.66 m) by 81.25 ft (24.76 m), for a total area of 660 m^2. Figure 4-3 shows the location of soil and vegetation samples at pad 37, as well as the location of the biological sample grid relative to the boundaries of the burn pad itself, both the approximate pad boundaries estimated from aerial photos (dotted line), and the surveyed pad boundaries determined from GPS walkover (solid line). The sampling grid, with a total area of 300 m^2, covers somewhat more than the southwest quarter of pad 37. Figure 4-4 is an enlargement of the vegetation sampling grid showing more clearly the individual soil and vegetation samples. Figures 4-3 and 4-4 illustrate two kinds of samples—soil samples collocated with vegetation samples (red squares), and vegetation samples only (green squares). In addition, soil samples collected during the RI/FS phases are indicated by black circles, green triangles, and red triangles to designate Phases I, II, and III, respectively. Burning pad 38 is approximately 72.5 ft (22.1 m) by 62.5 ft (19 m), for a total area of 421 m^2. Figure 4-5 shows the location of the pad 38 sampling grid relative to the pad itself, as well as the location of soil and vegetation samples taken on or adjacent to pad 38. The sampling grid covers the entire northern half of pad 38, extending into the southern half of the pad and slightly beyond the western boundary of the pad. Figure 4-6 is an enlarged view of pad 38 samples within the vegetation sampling grid.

Burning pads 58 and 59 are located on the northwest corner of WBG, and south of a road, as shown in Figure 1-1. Burning pad 58 is approximately 50 ft (15.24 m) by 100 ft (30.48 m), for a total area of 465 m^2. Figure 4-7 shows the location of pad 58's sampling grid within the boundaries of pad 58, except where the sampling grid extends approximately 4 m beyond the northern boundary. Figure 4-8 is an enlarged view of pad 58 samples within the vegetation sampling grid. Burning pad 59 is also approximately 50 ft (15.24 m) by 100 ft (30.48 m), for a total area of 465 m^2. Figure 4-9 shows the location of the vegetation sampling grid covering the majority of pad 59, with the western and northern grid boundaries shifted slightly west and north of the burning pad. Figure 4-10 is an enlarged view of the sampling grid on pad 59.

Burning pads 66 and 67 are located on the northern side of WBG, east of the center of the site and south of a road, as shown in Figure 1-1. Burning pad 66 is approximately 44 ft (13.4 m) by 75 ft (22.86 m), for a total area of 305 m^2. Figure 4-11 shows the location of the vegetation sampling grid of pad 66 as covering most of pad 66, with the western and northern grid boundaries extending slightly west and north of the burning pad. Figure 4-12 is an enlarged view of the grid on pad 66. Burning pad 67 is, like pad 66, approximately 44 ft (13.4 m) by 75 ft (22.86 m), for a total area of 305 m^2. Figure 4-13 shows the location of the vegetation sampling grid for pad 67. The grid covers more than the western half of pad 67, with the western and southern boundaries of the grid extending to the west and south of the burning pad. Figure 4-14 is an enlargement of that grid.

Tables 4-7 through 4-12 show the geographic distribution of metal, explosive, and propellant concentrations in surface soil. Chemicals in the soil are grouped by whether the samples were taken (1) inside the vegetation sampling grid and inside the burning pad boundaries, (2) inside the grid and outside pad boundaries, (3) outside the grid and inside the pad boundaries, or (4) outside both the grid and the pad. For chemicals from samples taken outside the grid and outside the pad boundaries (condition 4), the highest concentration for each chemical is selected from all the outside/outside samples (last column) for comparison with the chemical concentrations from the other locations, (1) through (3). In addition to sampling locations, the chemical samples are identified by the phase during which the samples were collected, i.e., Phase I or Phase II of the RI, Eco study (biological field-truthing), or Phase III (FS).

4.2.8 Comparison of Soil Concentrations Inside Grid Versus Outside for Pads 37 and 38

There was some concern that the position of the sampling grid relative to the pad 37 broundaries might result in the grid samples not being representative of the entire pad. A statistical test was conducted to determine if the soil concentrations measured within the grid were different from the soil samples taken outside the sampling grid but within the pad. Because the statistical tests for ecological effects were to be performed for pad pairs rather than individual pads, the statistical comparisons were made using data from both pads 37 and 38.

The samples considered inside the grid were the nine samples taken for this study plus samples from locations WBGss-030, WBGss-034, and WBGss-035 from the WBG Phase I RI and location WBG-232 from the WBG Phase III sampling. The samples considered outside the grid, but inside the pad, were from locations WBGss-031, WBGss-032, and WBGss-033 from the WBG Phase I RI; locations WBGss-153, WBGss-154, WBGss-175, and WBGss-187 from the WBG Phase II RI; and locations WBG-223 and WBG-231 from the Phase III sampling. The sampling locations were considered inside the pad based on the field-surveyed pad boundaries. Thus, there were 13 samples taken inside the grid and 9 samples taken outside the grid, but inside the pad, at pads 37 and 38.

Summary statistics were calculated for those inorganics and explosives detected both inside and outside the grid on pads 37 and 38 (Table 4-13). The number of results differs for some analytes because some metals were not included as target analytes in the Phase I study, and explosives were not measured in the laboratory unless there was a positive result during field screening for the RI sampling phases or for planned confirmatory samples. The Wilcoxon rank sum test was used to test for differences in concentration between the samples from inside the grid and those outside the grid but inside the pad. A two-tailed test was used with differences considered significant for $p<0.05$.

For all but four analytes, the concentration differences were not statistically different between the samples taken inside and those taken outside the grid. Barium and RDX were significantly higher outside the grid. Mercury and thallium were significantly higher inside the grid. The difference in thallium in an artifact of differences in detection limit among the studies. There were fewer thallium detects outside the grid so it

ranked lower than inside the grid. But for thallium, the detection limit for samples taken outside the grid was higher than the detection limit for samples taken inside the grid.

An examination of the average concentrations shows that the averages for some metals were higher inside the sampling grid and for others they were higher outside the grid. For example, considering lead and cadmium, the two metals with the highest HQ values from the ERA in the WBG Phase II RI, the mean concentrations of lead were 88 mg/kg inside the grid and 103 mg/kg outside the grid while the mean concentrations of cadmium were 76 mg/kg inside the grid and 11 mg/kg outside the grid.

These results indicate the metal concentrations were variable, but there were no systematic differences in contaminant concentrations inside versus outside the grids. Samples taken inside the grids were representative of the soil chemistry in the burning pad pair.

4.2.9 Discussion and Uncertainties

In these sampling efforts the selection of soil sample locations was biased toward a specific purpose. For the three phases of the RI, the sampling locations were generally biased on a small scale toward locations that would be expected to have the greatest contamination, such as areas with sparse or no vegetation and drainage pathways. The sampling was biased in an attempt to show the “worst-case” condition. The samples from the three phases of the RI were taken more frequently on the periphery of the pad where contaminant concentrations may be lower than toward the pad center. Consequently, the measured soil concentrations represent the local soil condition, but taken together the samples are not a statistically unbiased representation of the entire pad.

For the biological field-truthing study, soil samples were taken based on the degree of vegetation cover. For each pad pair three samples were taken at plots with bare-to-sparse vegetation cover, three at medium cover, and three at high cover. In the randomly sampled vegetation plots, a large majority of the plots had high vegetation cover. The biological field-truthing soil sampling over-represented the medium and sparse cover in relation to the pad as a whole. The average soil concentrations from the biological field-truthing sampling, therefore, may overestimate the average concentrations over the entire pad if medium and sparse cover areas have higher contaminant concentrations than high cover areas.

4.3 REFERENCE SITES

4.3.1 Selection of Reference Sites

Reference sites outside the WBG boundaries were selected to represent similar ecological conditions without AOC-related contamination. Originally, 20 potential reference sites were evaluated in order to duplicate as many of the WBG site characteristics as possible (Jent 2000a, 2000b; Groton 2000). Initial reference site selection was based on physical factors. After additional field surveys in March 2000, three paired sites were selected as comparable matches to the three pairs of burning pad sites at WBG. Soil surveys of Portage and Trumbull Counties (Ritchie et al. 1978; Williams 1992) were examined to ensure that the soil types for the burning pad and reference sites were pedologically similar. Hydrology, topography, type and degree of physical disturbance, degree of maintenance (i.e., mowing), and plant community type (i.e., surrounding habitat) similar to each pair of pads were also considered for reference site selections. Historical land use was investigated to ensure that the reference sites contained minimal contamination (i.e., no military-unique compounds) and that the desired small mammal species occurred on the site. Lastly, a prior survey of the small mammals at RVAAP verified that the target species did inhabit the area (Carroll 1999). Paired reference sites selected for each of the three burning pad pairs sampled in this

investigation are described in Table 4-14. Locations of the paired burning pads and their associated reference sites are shown in Figure 4-15.

The rationales for reference site selection give an indication of how the selection process occurred (Jent 2000a, 2000b; Groton 2000). For example, reference sites E1 and E2 were selected because vegetation and surrounding habitat mimic burning pads 37 and 38, and both the burning pad sites and the reference sites have slag. Sites S1 and S2 have pronounced berm-like structures and, like pads 58 and 59, lack slag. Sites J1 and J2 are large, open with a light strip of trees, and have a berm structure similar to that of the paired pads 66 and 67.

4.3.2 Sampling Grids

The sampling locations within the three reference sites were established during the vegetation sampling during the summer of 2000 (Figure 4-1). Each reference site was subdivided into two parts, each measuring approximately 15 by 20 m, during the vegetation sampling. Each part was further subdivided into 300 1- by 1-m plots, numeric identifications were assigned, and 27 plots were randomly selected for vegetation sampling using a random number generator.

For the follow-on soil sampling effort, the 27 previously selected 1- by 1-m vegetation plots in each part of the reference sites were located and flagged in the field in April 2002. Three to four of the 27 plots were randomly selected and flagged for soil sampling, which was done on May 9 and 10, 2002.

4.3.3 Field Sampling Methods

Seven representative surface soil samples from each of the three reference sites were collected from a depth range of 0 to 0.3 m (0 to 1 ft), for a total of 21 samples. Each of the 21 samples was subjected to laboratory analyses for explosives, target analyte list metals, cyanide, SVOCs, volatile organic compounds (VOCs), pesticides, and polychlorinated biphenyls. Additionally, one sample from each of the three reference areas was analyzed for propellants.

Surface soil samples analyzed for explosives and propellants were composite samples derived from three subsamples collected about 0.9 m (3 ft) from one another in a roughly equilateral triangle pattern, as described in the facility-wide SAP. Samples for all other analyses were discrete samples from a point located at the approximate center of the triangle. VOC analyses were collected at the center of the interval (0.5 ft) immediately upon extraction from the boring, unless a zone of obvious contamination was observed.

In accordance with the facility-wide SAP, if a zone of obvious contamination was observed, then the VOC sample was to be collected from that zone. No obvious contamination was observed at any location. A portable GPS was used to obtain final coordinate locations of each soil sample.

Field QC consisted of field duplicates and split samples at a frequency of approximately 10%. Two (2) field duplicates and two (2) USACE QA split samples were collected during the sampling event. Split samples were submitted to the USACE contract laboratory for independent analysis for QA testing. Duplicate and split samples were derived from the same sampling station, selected on a random basis, and submitted for the same analyses as the environmental samples. Two rinsate blanks were collected for surface soil equipment. Trip blanks accompanies all shipments containing aqueous VOCs.

Because sample locations were in non-AOC settings, excess soil cuttings from surface soil locations were used to backfill the 0- to 1-ft surface soil borings. In the case where insufficient excess soil cuttings were available to backfill the boring, the borings were topped off with bentonite chips.

No unexploded ordnance (UXO) avoidance support was required during the reference area sampling effort.

4.3.4 Analytical Methods

STL's QMP, Section 8.0, and the facility-specific addenda for the North Canton, Knoxville, and Sacramento, California, facilities were followed during the analysis of reference site samples. Laboratory SOPs were implemented using EPA methods (Table 4-15).

Table 4-15 lists the numbers and types of soil and water samples for each analytical test. In addition, there was a full suite of TCLP tests for the IDW soil and water.

4.3.5 Comparison of Reference Soil Data to Background and Ecological Screening Values

The reference sites were evaluated to quantitatively and qualitatively assess their suitability for comparison to the WBG pads. This evaluation consisted of:

(1) comparison of maximum soil concentrations to the RVAAP facility-wide background criteria;

(2) statistical comparison of the average concentrations at the reference sites to the average concentrations from the background samples;

(3) comparison of maximum reference concentrations with Ecological Screening Values (ESVs); and

(4) qualitative assessment based on site-specific considerations, such as prior land use at the reference sites.

(1) Facility-wide Background Comparison. The maximum levels at the reference sites were compared to concentrations measured during the RVAAP facility-wide background study to determine if the concentrations at the reference site were higher than would be expected for a site uncontaminated by RVAAP activities.

Two approaches were employed to compare reference site data to facility-wide background values. The first approach used the facility-wide background criteria presented in the WBG Phase II RI Report (USACE 2001) and used in subsequent RI reports. These criteria are the lower of the maximum detected concentration or the 95% upper tolerance limit of the 95th percentile (95% UTL) for each metal. Facility-wide background criteria were not developed for organic compounds. These criteria were based on a subset of 11 of the 15 surface soil samples taken as part of the facility-wide background study. Four samples (BK0788, BK0794, BK0795, and BK0798) were considered outliers for the background determination and were not included in the background criteria calculations by agreement of Ohio EPA, the Army, and SAIC during the preparation of the Winklepeck Burning Ground Phase II RI Report.

The second approach used background values (UTL values) calculated from all 15 of the facility-wide background surface soil samples collected. Evaluation of the four outlier samples removed from the development of the facility-wide background criteria indicated that they were from areas disturbed by pre-RVAAP farming and homestead activities. Because the reference sites are also disturbed sites, it was determined to be most appropriate to compare them to facility background UTLs derived from the entire population of background sites.

For background values using all 15 samples, the UTL was calculated based on the probability distribution of the results. If the distribution was normal, untransformed data were used to calculate a 95% UTL. If the distribution was lognormal, log-transformed data were used to calculate a 95% UTL. If the probability distribution could not be determined, the maximum detected value was used as a nonparametric UTL. The UTLs were calculated for organic constituents where sufficient data were available, as well as metals.

The background UTLs calculated from the 15 samples and the facility-wide background criteria calculated from the 11 samples are shown in Table 4-16. The UTLs calculated from all 15 background samples were higher than the facility-wide background criteria based on 11 samples. The differences are the result of higher concentrations in some of the four outlier samples and in using the 95% UTL or maximum detect rather than the lower of the 95% UTL or the maximum detect, as was done in the WBG Phase II RI.

If the concentrations at the reference site were similar to background concentrationsbased on the 95% UTL, there should be less than a 5% chance that the reference value was greater than the background value. Finding results greater than the background value (either 95% UTL or maximum detect) suggests that further evaluation is warranted (see step number 2, below). If a constituent was not detected in the background data set, but was presented at a reference site, it was carried forward to the ESV screen (step 3 below).

(2) Statistical Comparison of Averages. For those analytes with concentrations at the reference sites that exceeded the background criteria, the reference average (or median) concentrations were compared to the average (or median) background concentrations using the t-test or Wilcoxon rank sum test as appropriate for the data distribution. These tests determine if the concentrations overall from the reference site are shifted higher than the background site. This is in contrast to the initial background comparison that only considered the highest reference site concentration. A probability was calculated to assess the chance that the observed differences between the reference and background samples could result from chance if the concentration distributions were really the same for the two groups of samples. Probability values less than 0.05 (based on the α level of 5% selected by the project team) were considered to indicate statistically significantly higher concentrations in the reference site samples than the background samples. The following assumptions were made for the statistical comparisons:

- For calculation of the averages and computation of the t-test statistic, results considered nondetects were included in the calculations using one-half the detection limit as a surrogate for the result.

- For the Wilcoxon rank sum test, results for nondetects were set to zero. Setting nondetects to zero makes all nondetects tied at the lowest rank, which is appropriate for a nonparametric test.

- The t-test was used for comparisons in which the data distribution from both the reference and background sample groups was not statistically significantly different from normal based on the Shapiro-Wilk test ($p>0.05$).

- The Wilcoxon rank sum test was used if either the reference or background distribution was lognormal, statistically significantly different from normal and lognormal, or undetermined because of more than 50% nondetect results.

- Averages and statistics for the facility-wide surface soil background were calculated for two datasets. One set included the 11 samples used for the facility-wide background criteria calculation (i.e., four outliers excluded). The other set included all 15 facility-wide background surface soil samples; this latter set was used to determine which constituents would be further evaluated using ESVs.

- The statistical comparisons made were one-tailed tests that asked: “Was the average or median reference concentration significantly greater than the average or median background concentration?”

The organic compounds were detected less frequently than the metals. Quantitative comparisons were made between organic concentrations at the reference and background sites as data permitted.

(3) ESV Comparison. Those metals and organics whose average concentrations were statistically at higher than the average background concentrations (based on all 15 samples) were further evaluated by comparison with ESVs. Ranges of ESVs were taken from the literature. The average and maximum concentrations from the reference sites were compared to determine if the concentrations exceeded the upper ESV for each chemical. Soil concentrations below the upper ESV would require no further ecological evaluation.

(4) Site-Specific Considerations. Chemicals whose reference site concentrations exceeded the background values in steps (1) and (2) and exceeded the ESV ranges in step (3) were qualitatively assessed with respect to previous RVAAP land use, reference site land use, and other site-specific considerations such as geology and soil type.

4.3.6 Results for Reference Soil Sites

All of the analytical results for the reference sites soil chemistry are presented as Attachment 1 at the end of this chapter.

E1/E2 (Reference Site for Pads 37/38). E1/E2 was the reference site for WBG pads 37/38. The E1/E2 site had been graded, covered with slag (material from coke ovens), and used to store materials. Table 4-17 provides the summary statistics for each analyte detected in the reference samples and also the initial comparison of background criteria (11 samples) and reference soil data. Antimony, selenium, and silver were not detected in any soil samples from site E1/E2. Of the metals detected, chromium, cobalt, lead, manganese, nickel, vanadium, and zinc never exceeded the background criteria. Cadmium and thallium were detected in the reference samples but were not detected in the RVAAP background soil. The concentrations of these two metals detected at the reference site were less than the detection limit achieved during the background study so these detections would not be considered above background levels.

When the maximum inorganic concentrations were compared with the background UTLs based on all 15 background samples, the concentrations of six additional analytes were below the background UTL (Table 4-18). These analytes were aluminum, barium, calcium, cyanide, mercury, and potassium.

For those inorganics whose maximum concentrations at the reference site were greater than the 11-sample, facility-wide background criteria (aluminum, arsenic, barium, beryllium, calcium, copper, iron, magnesium, mercury, potassium, and sodium; Table 4-17), the t-test or Wilcoxon rank sum test was used, depending on the sample distribution, to test if the average (or median) values of the reference samples were greater than the background samples (Table 4-19). (Beryllium has a different basis for comparison; it was compared to the subsurface background because the subsurface background data were used to compute the background criteria for surface soils.) These tests indicated a statistically significant difference of the average concentrations of aluminum, beryllium, magnesium, potassium, and sodium between the reference and 11 background samples.

The t-test or Wilcoxon rank sum test was also applied using the 15-sample background population (Table 4-20). Of those inorganic analytes with maximum concentrations that exceeded the 15-sample background UTLs (Table 4-18), arsenic, copper, iron, and sodium were not greater than background based on the t-test or Wilcoxon rank sum test. Those metals whose average concentrations exceeded the background average concentrations were further evaluated using ESVs (beryllium and manganese).

For metals requiring further evaluation and those chemicals for which background criteria were not established, the average and maximum concentrations were compared to a range of ESVs (Table 4-21). For all chemicals, neither the maximum detected concentration nor the average concentration exceeded the upper value in the ESV range. This indicated that while there were some inorganics found at the

reference site at concentrations above background and some organic compounds detected, these chemicals were at concentrations that would not be expected to cause ecological harm.

No explosives or propellants were detected at this reference site. Seventeen SVOCs were detected (Table 4-17). Most of these compounds were PAHs. PAHs are associated with combustion products and are often found at background sites near human activities. There were no PAHs for which the concentrations were significantly different statistically from the 15-sample background data (Table 4-20).

Five VOCs were detected at reference site E1/E2 (Table 4-17): dimethylbenzene, ethylbenzene, methylene chloride, tetrachloroethene, and toluene. All concentrations of volatile organics were less than 0.02 mg/kg. None of the concentrations of volatile organics exceeded the upper ESVs (Table 4-21); therefore, no ecological impact is associated with them.

S1/S2 (Reference Site for Pads 58/59). S1/S2 was the reference site for pads 58/59. The area had been used as a borrow pit and had little or no slag covering. Antimony, cadmium, cyanide, selenium, silver, and sodium were not detected in any samples from site S1/S2 (Table 4-22). Of the metals detected, aluminum, arsenic, beryllium, calcium, lead, manganese, mercury, and vanadium never exceeded the 11-sample background criteria. Thallium was detected in the reference samples but was not detected during the background study. The concentrations of thallium detected at the reference site were less than the detection limit achieved during the background study so these detections would not be considered above background levels.

When the maximum inorganic concentrations were compared with the background UTLs based on all 15 background samples, the concentrations of five additional analytes were below the background UTL (Table 4-23). These analytes were barium, chromium, magnesium, potassium, and zinc.

The maximum concentrations of some of the metals at the reference site were greater than the facility-wide background criteria based on the 11 samples. These metals include barium, chromium, cobalt, copper, iron, magnesium, nickel, potassium, and zinc (Table 4-22). For these metals, the t-test or Wilcoxon rank sum test was used, depending on the sample distribution, to test if the average (or median) values of the reference samples were greater than the background samples (Table 4-24). These tests indicated a statistically significant difference of the average concentrations of chromium, copper, iron, magnesium, nickel, potassium, and zinc between the reference site and the 11 background samples.

The t-test or Wilcoxon rank sum test was also applied using the 15-sample background (Table 4-25). Of those inorganic analytes with maximum concentrations that exceeded the 15-sample background UTLs (Table 4-23), copper was not greater than background based on the t-test or Wilcoxon rank sum test. Those metals whose average concentrations exceeded the background average concentrations were further evaluated using ESVs (cobalt, iron, and nickel).

For metals requiring further evaluation and those chemicals for which background criteria were not established, the average and maximum concentrations were compared to a range of ESVs (Table 4-26). For most chemicals, neither the maximum detected concentration nor the average concentration exceeded the upper value in the ESV range. This indicates that while there were some chemicals found at the reference site at concentrations above background, they were at concentrations that would not be expected to cause ecological harm. Only the maximum and average iron concentrations did exceed the range of ESVs. However, the average iron concentration for the background samples (Table 4-16) also exceeded the ESV range. The implications of this comparison are discussed in Section 4.3.7.

No explosives or propellants were detected at this reference site. Two SVOCs, benzoic acid and bis(2-ethylhexyl)phthalate, were detected (Table 4-22). Bis(2-ethylhexyl)phthalate concentrations were not

statistically different from the 15-sample background (Table 4-25). There were no background data or ESVs for benzoic acid, which had a maximum concentration of 0.23 mg/kg (Table 4-26).

Three VOCs were detected at reference site S1/S2 (Table 4-22): dimethylbenzene, methylene chloride, and toluene. All concentrations of volatile organics were less than 0.003 mg/kg, and all were less than both lower and upper ESVs (Table 4-26).

J1/J2 (Reference Site for Pads 66/67). J1/J2 was the reference site for pads 66/67. The area had been an unpaved airstrip. Antimony, cadmium, cyanide, selenium, silver, and sodium were not detected in any samples from site J1/J2 (Table 4-27). Of the metals detected, arsenic, barium, beryllium, calcium, lead, and manganese never exceeded the facility-wide background criteria based on 11 samples. Thallium was detected at the reference site but at concentrations below the detection limit achieved during the facility-wide background study.

When the maximum inorganic concentrations were compared with the background UTLs for all 15 background samples, the concentrations of six additional analytes were below the background UTL (Table 4-28). These analytes are aluminum, magnesium, mercury, potassium, vanadium, and zinc.

The maximum concentrations of some of the metals at the reference site were greater than the 11-sample, facility-wide background criteria. These metals include aluminum, chromium, cobalt, copper, iron, magnesium, mercury, nickel, potassium, vanadium, and zinc (Table 4-27). For these metals, the t-test or Wilcoxon rank sum test was used, depending on the sample distribution, to test if the average (or median) values of the reference samples were greater than the background samples (Table 4-29). These tests indicated a statistically significant difference of the average concentrations of aluminum, chromium, cobalt, copper, iron, magnesium, nickel, potassium, vanadium, and zinc between the reference and the 11 background samples.

The t-test or Wilcoxon rank sum test was also applied using the 15-sample background (Table 4-30). Of those metals with maximum concentrations that exceeded the 15-sample background UTL (Table 4-28), copper was not greater than background based on the t-test or Wilcoxon rank sum test. Those metals whose average concentrations exceeded the background averge concentratinos were further evaluated using ESVs (chromium, cobalt, iron, and nickel).

For metals requiring further evaluation and those chemicals for which background criteria were not established, the average and maximum concentrations were compared to a range of ESVs (Table 4-31). For most chemicals, neither the maximum detected concentration nor the average concentration exceeded the upper value in the ESV range. This indicates that while there were some chemicals found at the reference site at concentrations above background, they were at concentrations that would not be expected to cause ecological harm. Only the maximum and average iron concentrations did exceed the range of ESVs. However, the average iron concentration for the background samples (Table 4-16) also exceeded the ESV range. The implications of this comparison are discussed in Section 4.3.7.

Neither explosives nor propellants were detected at this reference site. Four SVOCs were detected (Table 4-28) in only two samples: bis(2-ethylhexyl)phthalate, benzoic acid, fluoranthene, and pyrene. The maximum concentration detected of the semivolatile compounds was less than 0.2 mg/kg. The maximum concentrations of fluoranthene and pyrene did not exceed the 15-sample background UTL (Table 4-28). Bis(2-ethylhexyl)phthalate concentrations were not statistically different from the 15-sample background (Table 4-30). There were no background data or ESVs for benzoic acid, which had a maximum concentration of 0.23 mg/kg.

Three VOCs were detected at reference site J1/J2 (Table 4-27): dimethylbenzene, ethylbenzene, and toluene. All concentrations of volatile organics were less than 0.007 mg/kg and were below their respective ESVs (Table 4-31).

4.3.7 Site-Specific Considerations, Discussion and Uncertainty

Only iron was present within the reference sites at concentrations that exceeded background average concentrations and the range of ESVs. Iron was slightly elevated relative to RVAAP background (less than two times) and was detected at concentrations higher than the range of ESVs at reference sites S1/S2 and J1/J2. Although the average iron concentrations at these two reference sites were over 100 times larger than the ESV for iron, the RVAAP background concentration is also about 100 times larger than the ESV. Thus, no discernible difference between the reference sites and the RVAAP background locations would be anticipated. This section provides additional evaluation of this constituent with respect to site-specific conditions.

Metals like iron are expected to be variable in soils that originated from glacial till. The glacial history of the RVAAP area results in soils derived from mixtures of parent material. Soil chemistry may vary from place to place depending on the chemistry of the parent material deposited at that place. The elevation of some metals relative to background may be a reflection of natural variability of the soil. The RVAAP background 95% UTL value for iron allows for a 5% probability that concentrations from areas not different from background may exceed the 95% UTL due to normal variability. For many analytes the maximum detect was used as the background criteria, adding conservatism as to the proportion of results that may be expected to exceed the criteria from natural variability.

The references sites were chosen because they were disturbed on a timeframe similar to the paired WBG sites. Therefore, they were not pristine nor were they meant to be pristine sites. Disturbances would have included the use of earth-moving equipment for clearing and grading the soil at each of the three reference sites. Slag placed at E1/E2 also may contribute to the presence of some metals at this site. The RVAAP installation also has a long land-use history that pre-dates RVAAP. Historical activities, such as farming, may have contributed some level of constituents to the soils at the reference sites. The types of chemicals found at the reference sites are chemicals expected from general human use activities: metals, PAHs, traces of fuels, and fertilizers.

RVAAP facility-wide background sites considered undisturbed by RVAAP activities also had variable concentrations of some metals and detected organics as reflected in the concentrations in the four samples considered outliers in that study. All of the sampling sites selected for facility-wide background study had no known historical use by RVAAP. These sites had detectable concentrations of PAHs. Four of 15 sites selected were considered outliers because of elevated concentrations of two or more of the following chemicals: antimony, beryllium, cyanide, lead, magnesium, and PAHs.

Using the 11-sample background comparison, aluminum was slightly elevated relative to RVAAP background (less than two times) and was detected at concentrations higher than the range of ESVs at reference sites E1/E2 and J1/J2. Recent studies have shown that aluminum is not bioavailable to plants at soil pH values >5.5. Soil pH measurements taken at WBG and background sites during the Phase II RI at WBG were all between pH 8 and 9. So despite the apparent elevation in aluminum concentrations, it would not be expected to be bioavailable, and without an exposure mechanism, there would be no opportunity for risk.

4.3.8 Reference Site Summary

The reference sites qualify for their intended purposes. The comparison of chemical concentrations at the reference sites with the facility-wide background concentrations and ESVs indicated that the reference sites and background locations are similar. Further, the chemicals that are of ecological concern at the WBG sites should not impact the reference sites. Convincingly, explosives and propellants—present at WBG—were not detected at any of the reference sites. The reference sites had low concentrations of the metals of primary concern at WBG, cadmium and lead. All elevated metal concentrations, except iron, and detected organic compounds were within the range of ESVs. This means that those chemicals that were present at the reference site were not present at concentrations that would be expected to cause ecological harm. There was evidence of minor contamination at the reference sites by iron. This was expected because the reference sites were not meant to be pristine. Although iron exceeded the ESVs for the reference sites, the background value also exceeds the ESVs. In short, each of the reference sites was appropriately selected not only from a soil, vegetation, topographic, and use-history viewpoint, but also from a chemical concentration viewpoint.

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FIGURES

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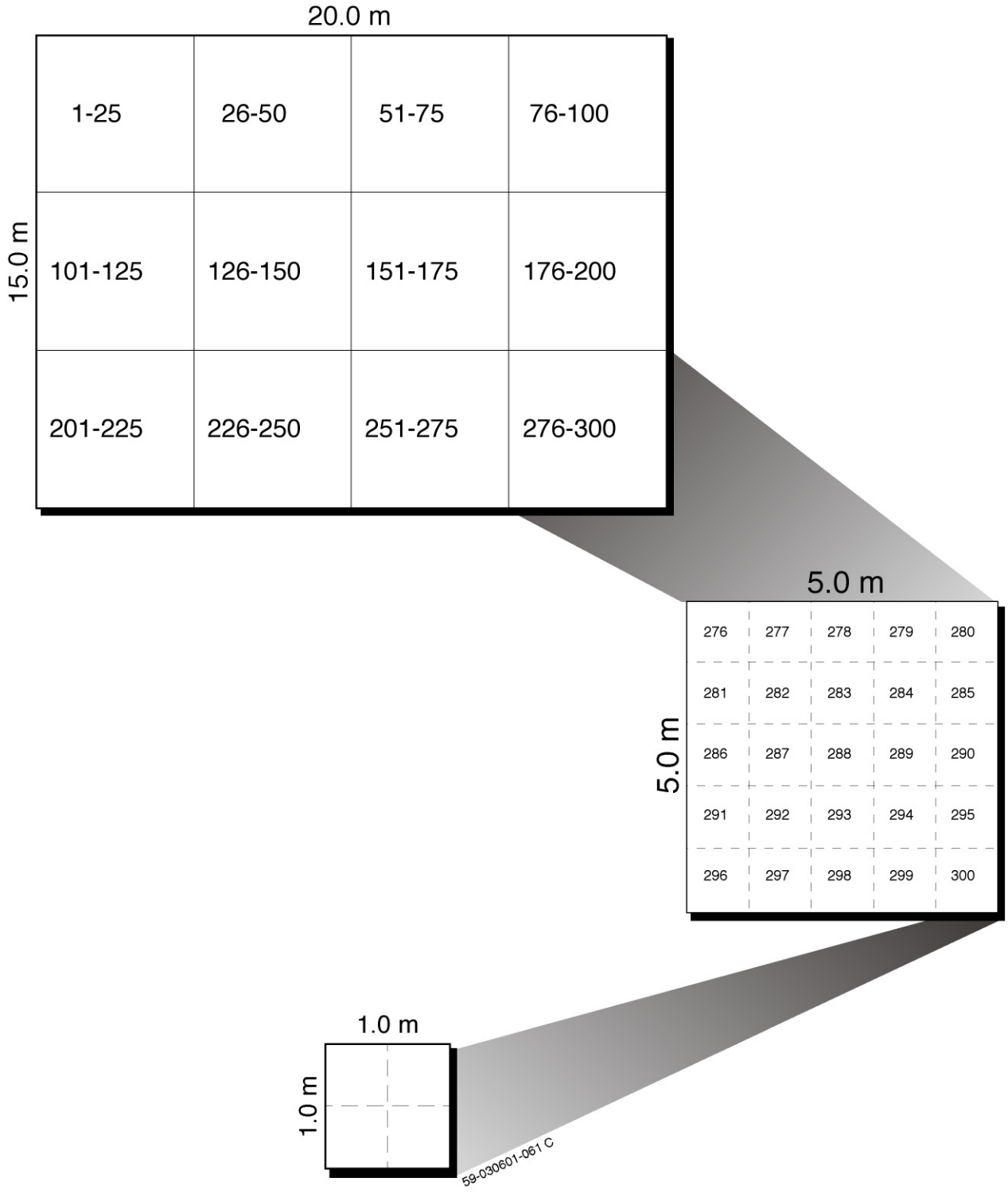
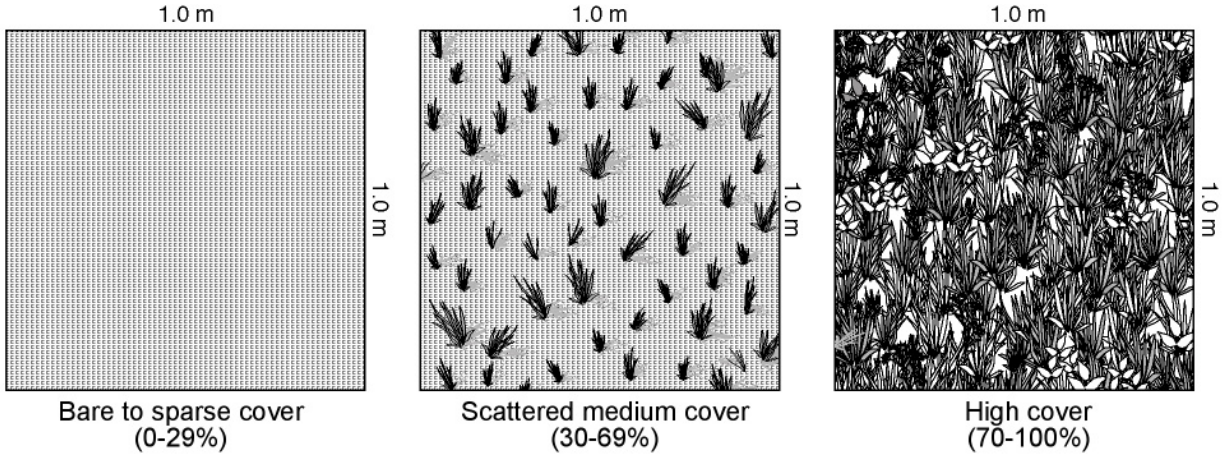
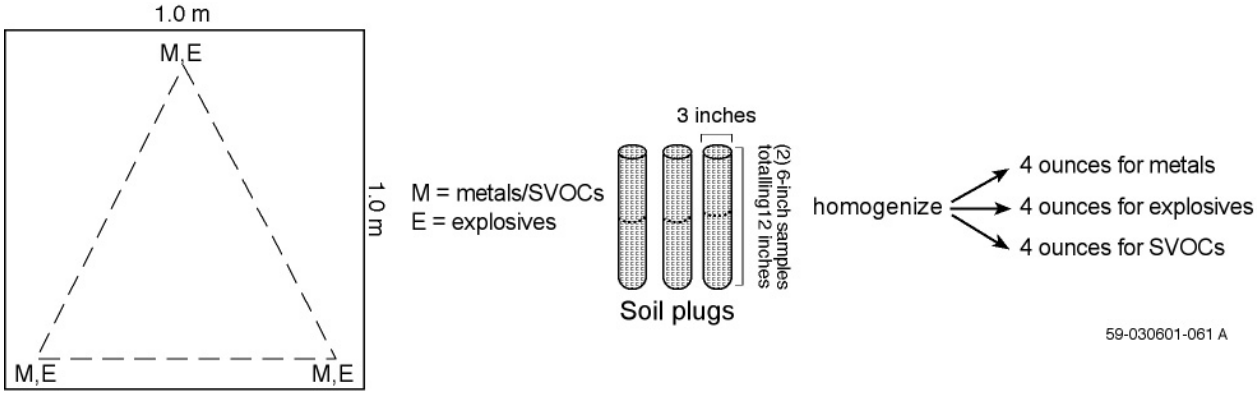


Figure 4-1. Sampling Grids at Burning Pad Sites and Reference Sites



Types of vegetation cover in stratified sampling



Sampling locations for soil at each of
9 plots at burning pad pairs

Figure 4-2. Vegetation and Soil Measurements Within Plots at Burning Pad Sites

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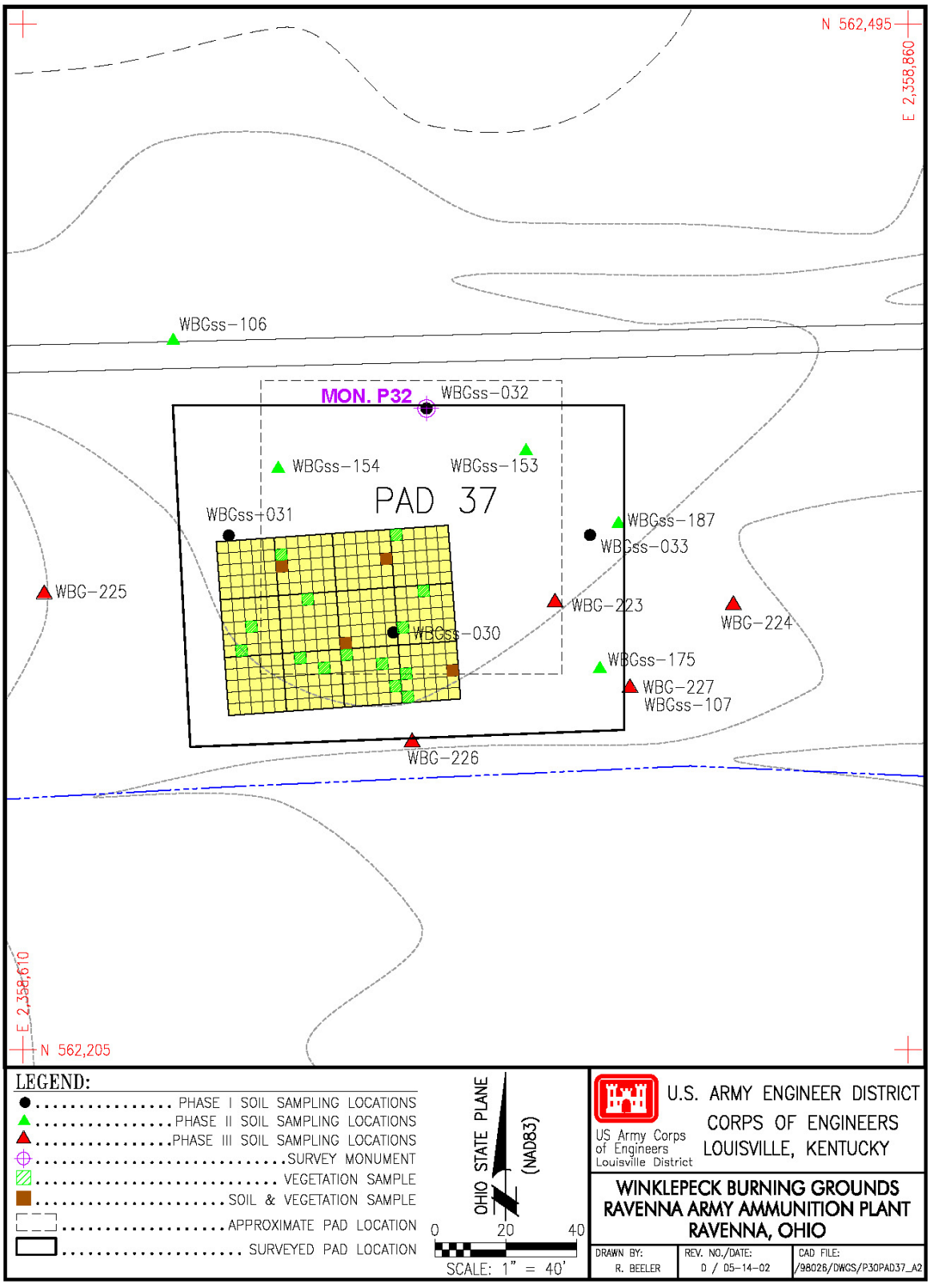

Figure 4-3. Pad 37 Sample Locations: Pad Boundaries

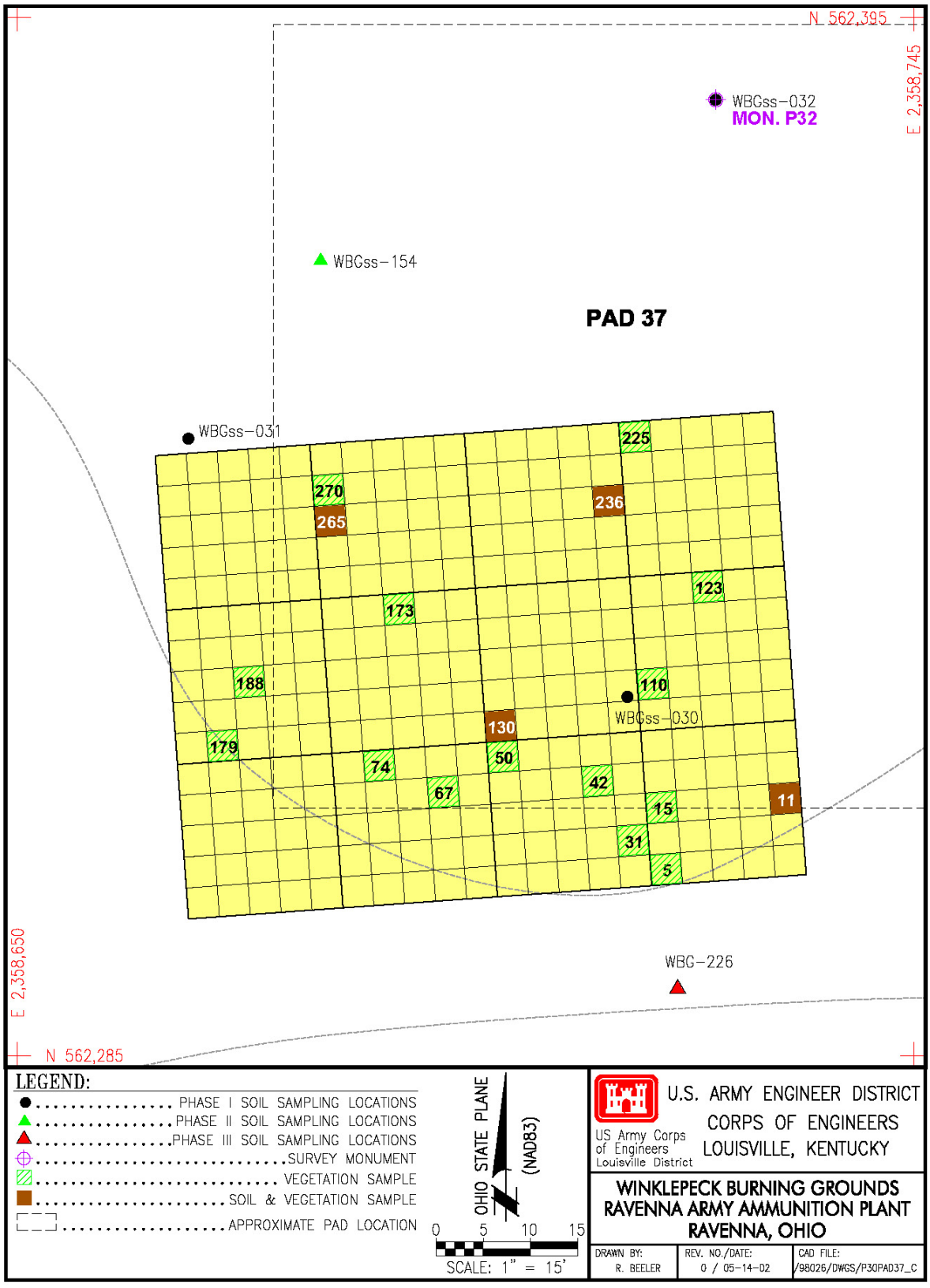

Figure 4-4. Pad 37 Sample Locations: Blowup

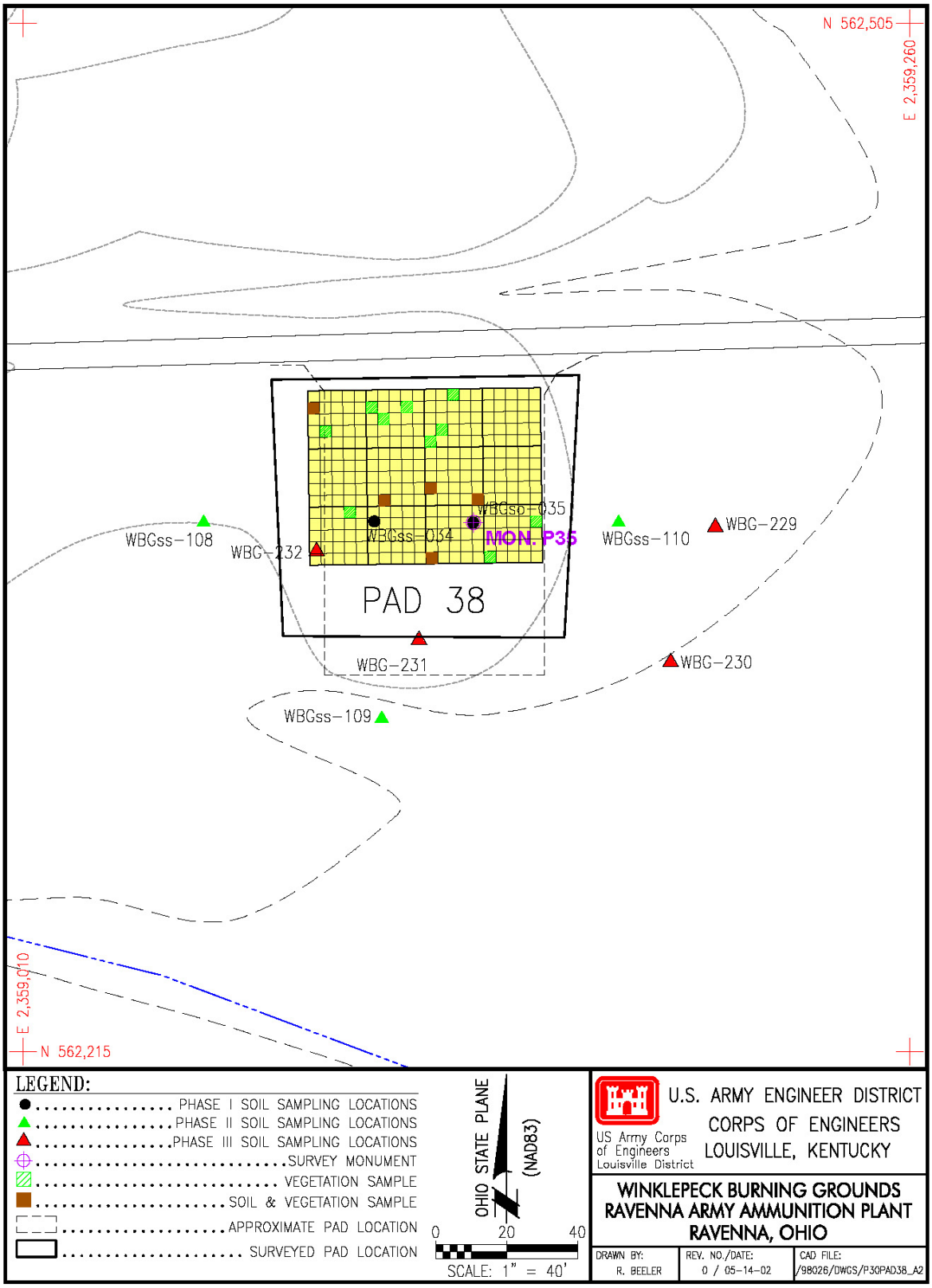

Figure 4-5. Pad 38 Sample Locations: Pad Boundaries

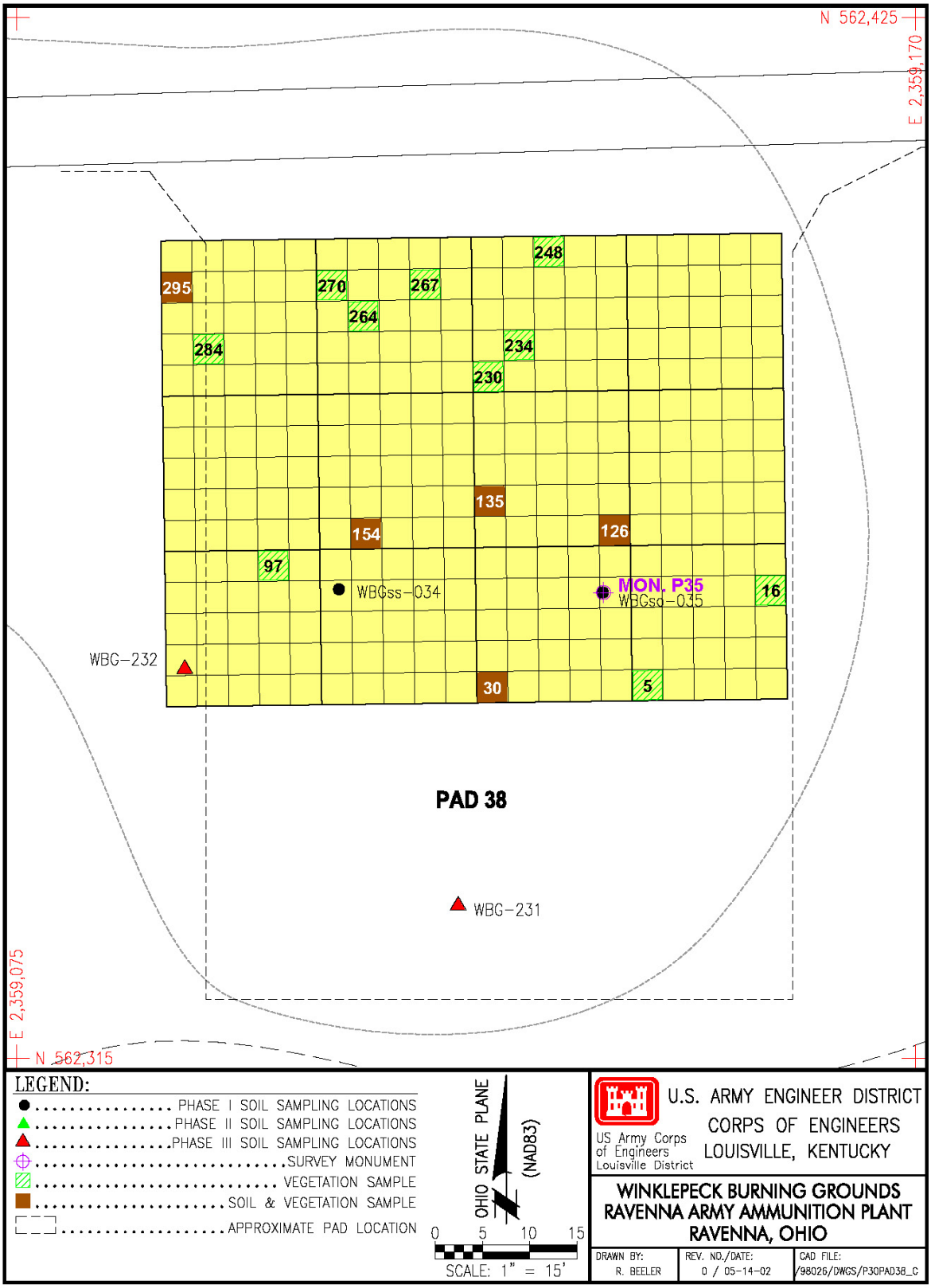

Figure 4-6. Pad 38 Sample Locations: Blowup

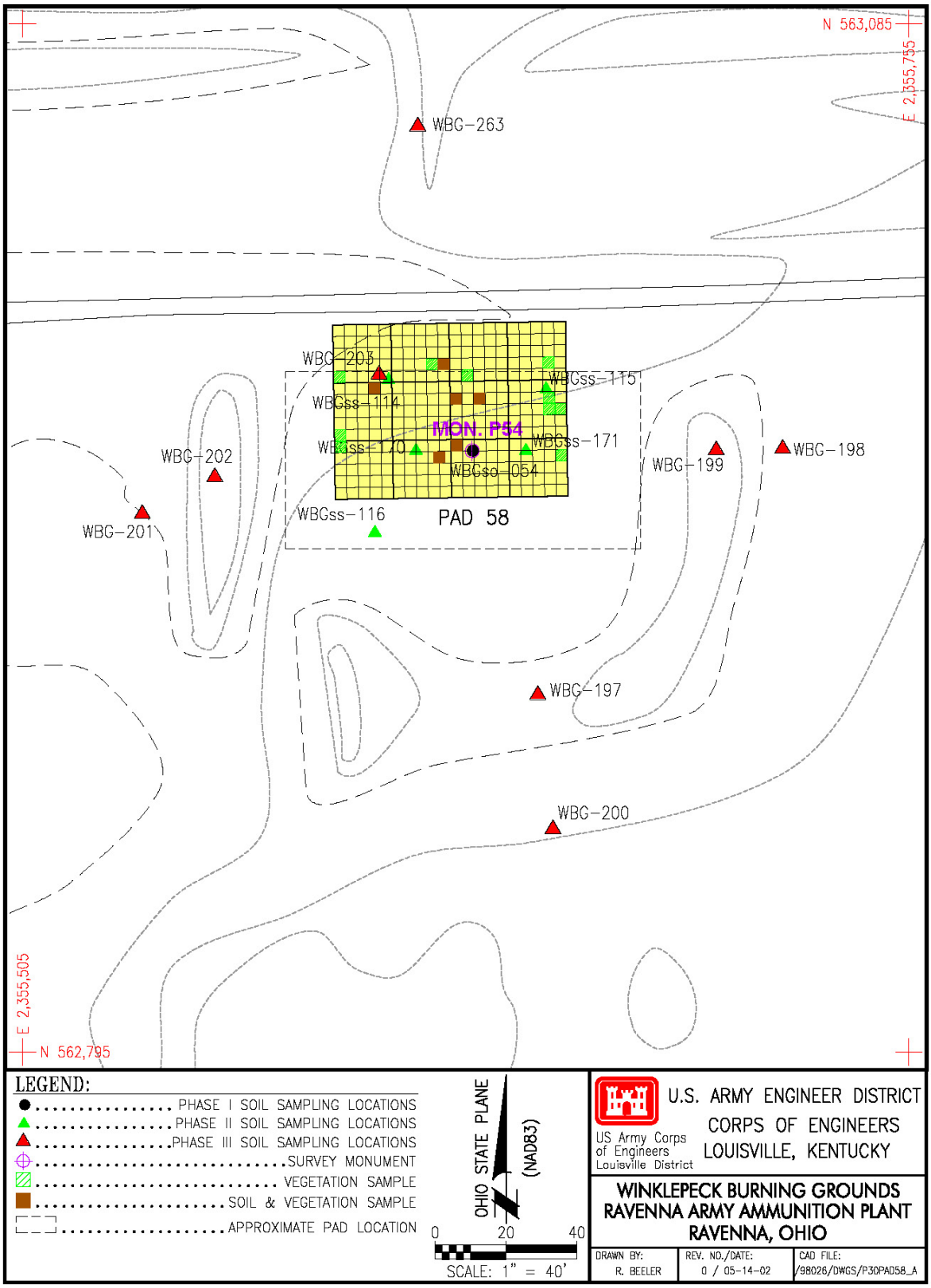

Figure 4-7. Pad 58 Sample Locations

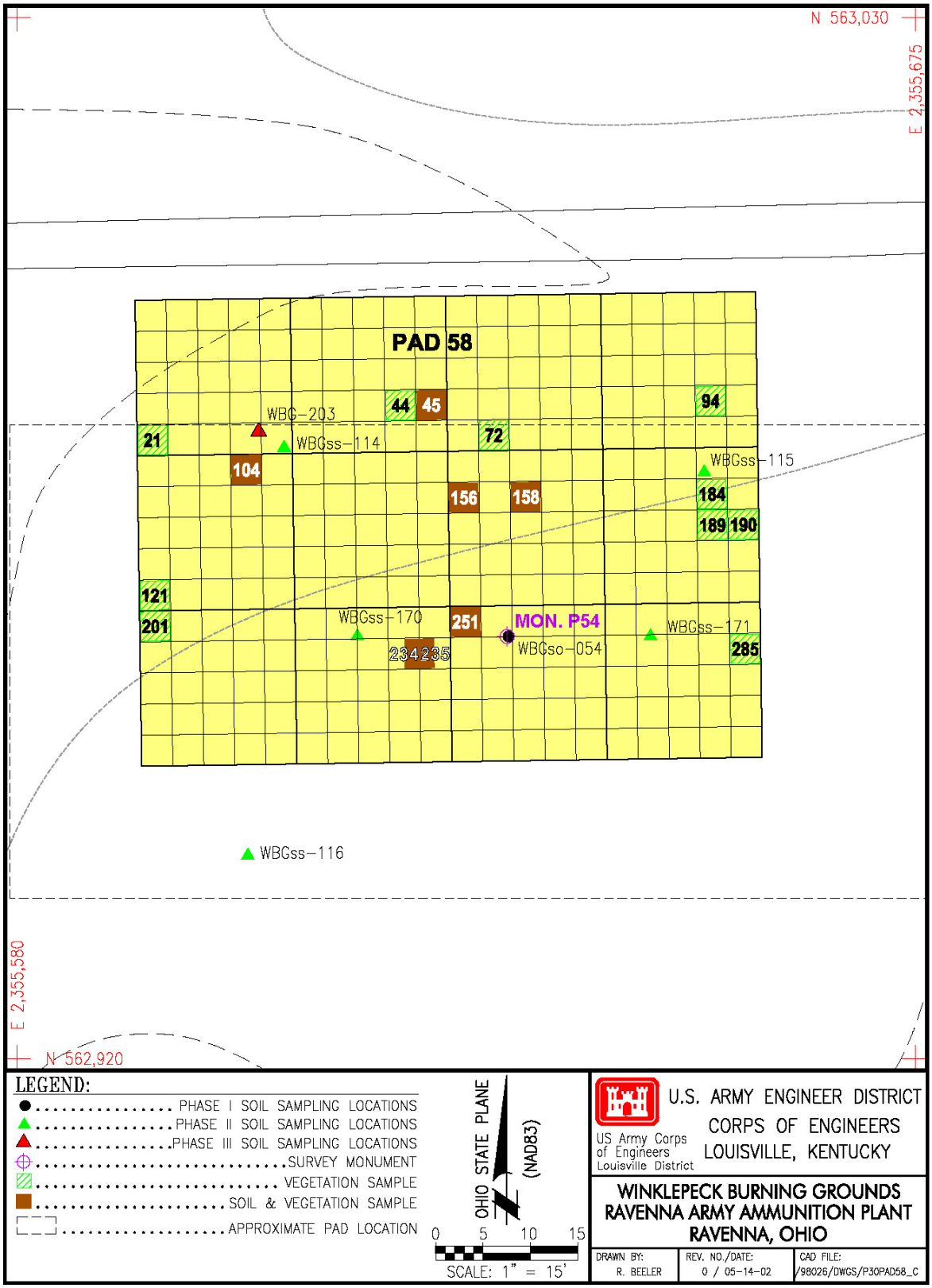

Figure 4-8. Pad 58 Sample Locations: Blowup

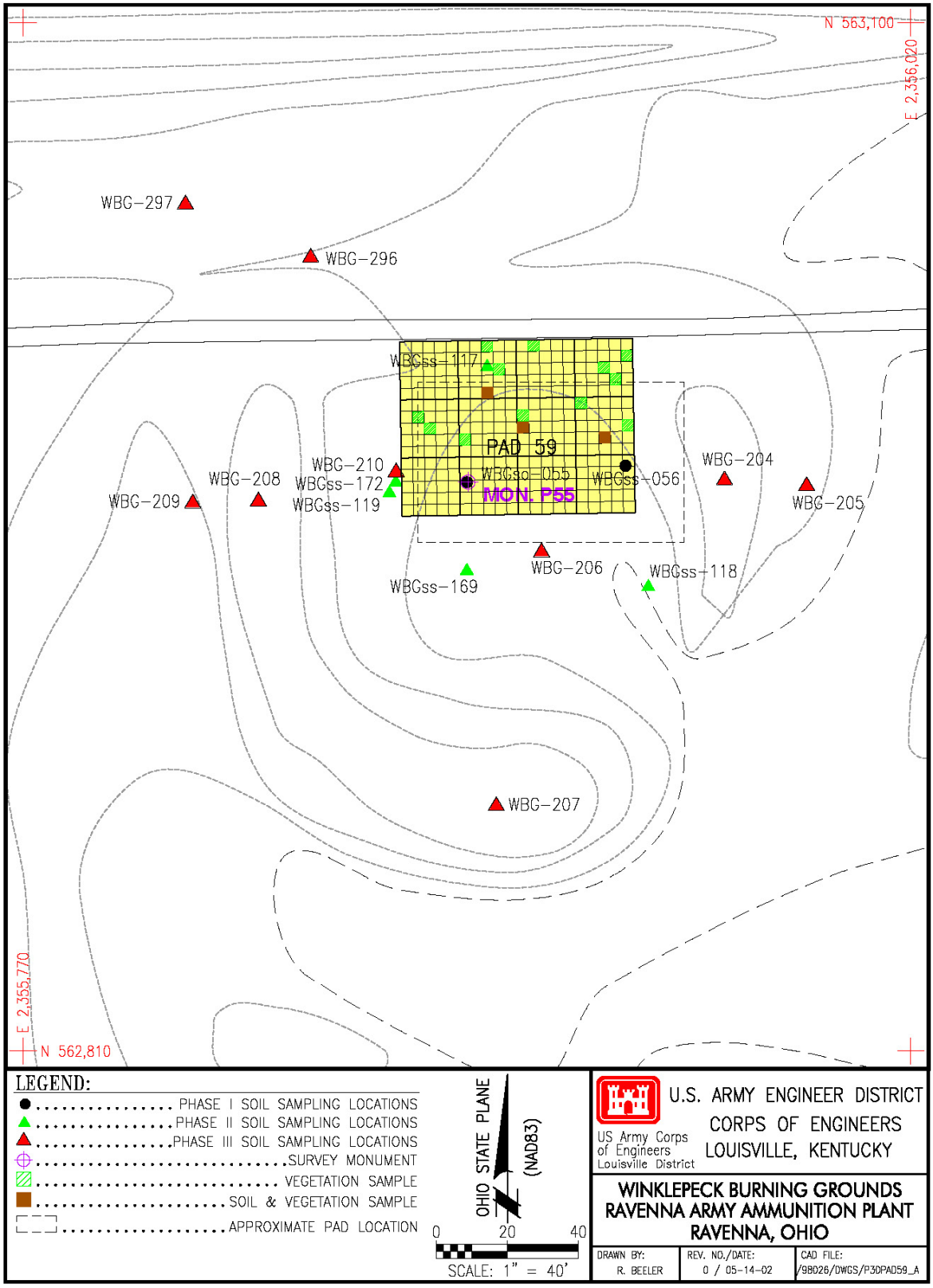

Figure 4-9. Pad 59 Sample Locations

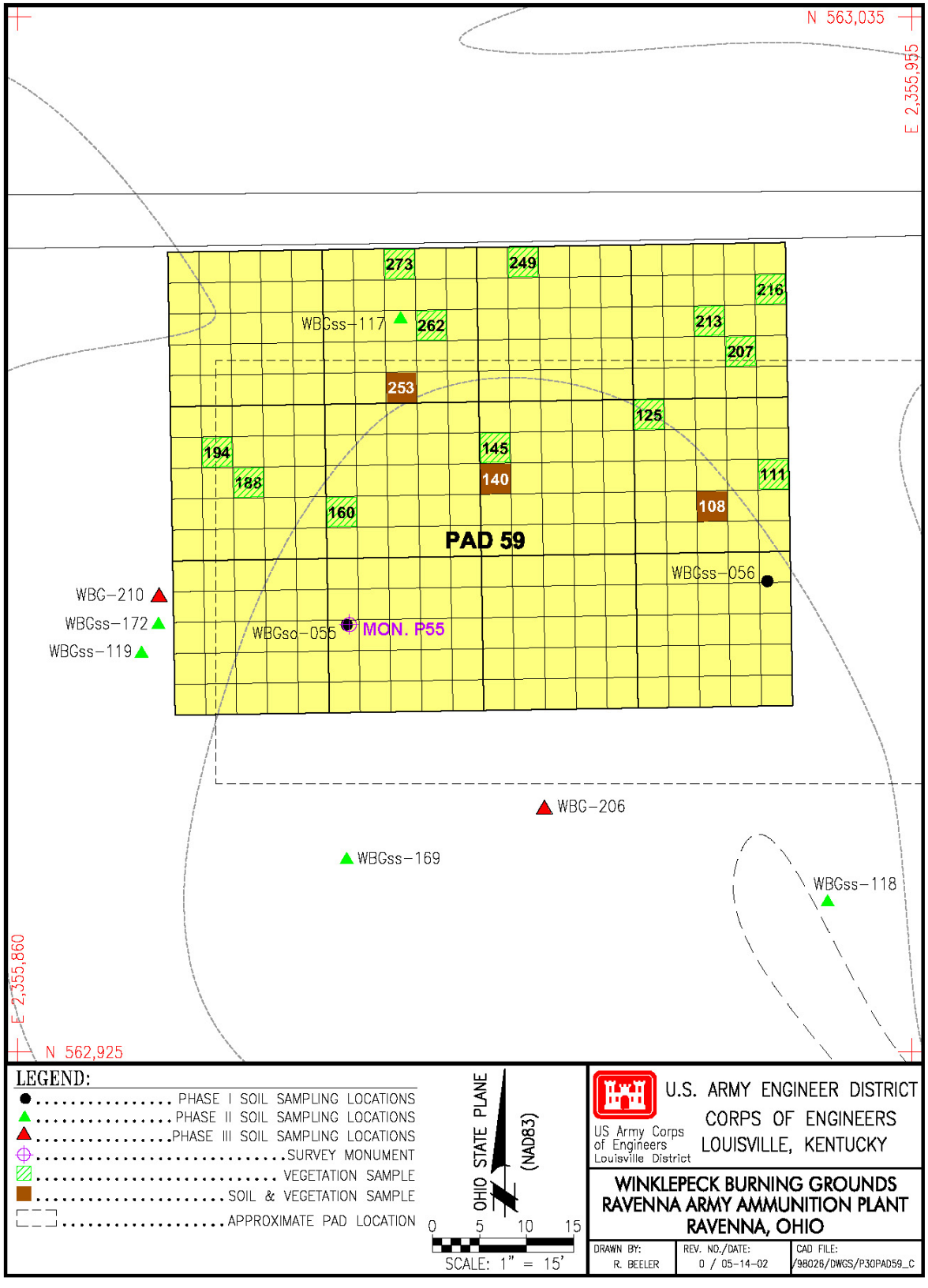

Figure 4-10. Pad 59 Sample Locations: Blowup

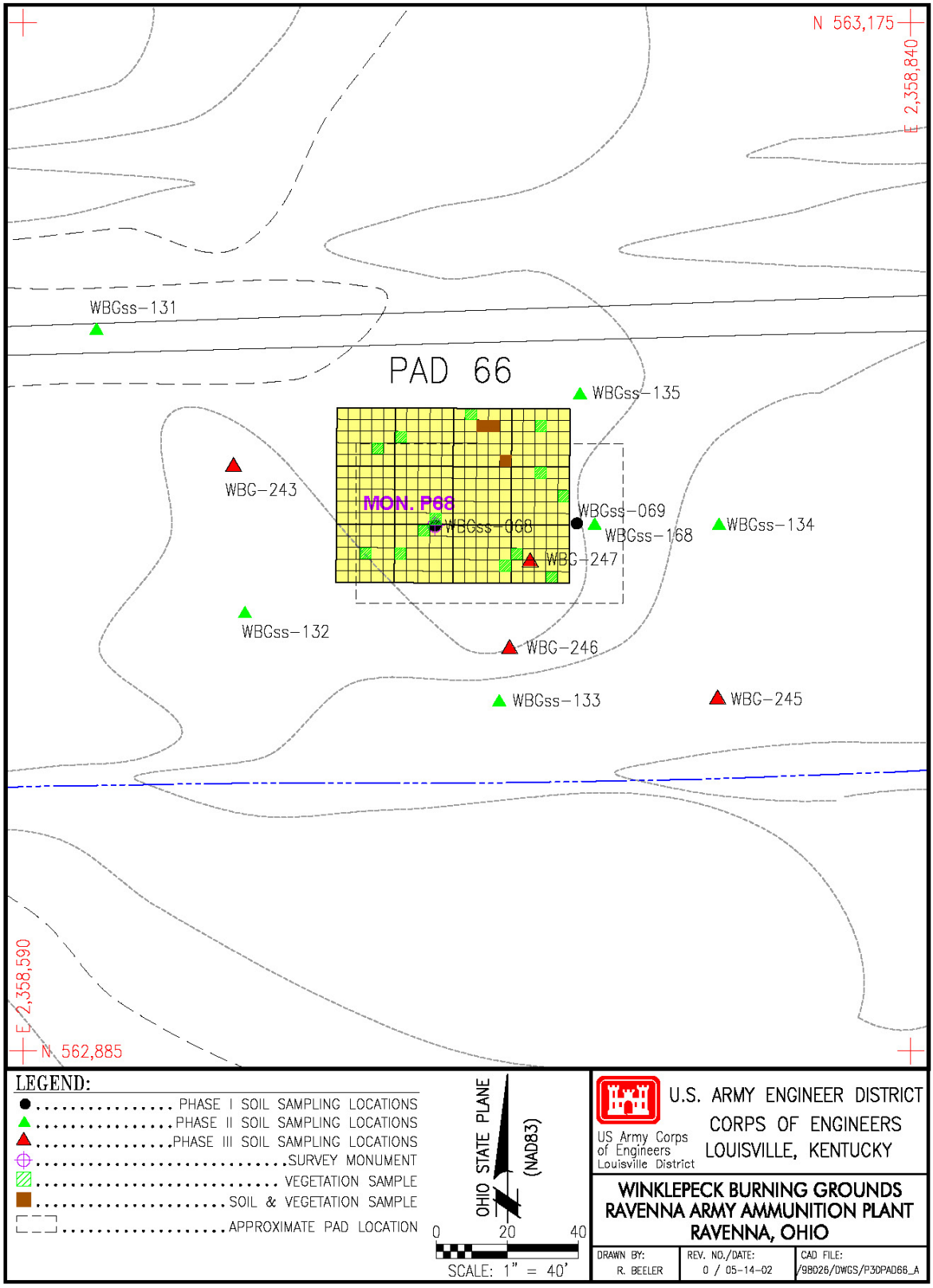

Figure 4-11. Pad 66 Sample Locations

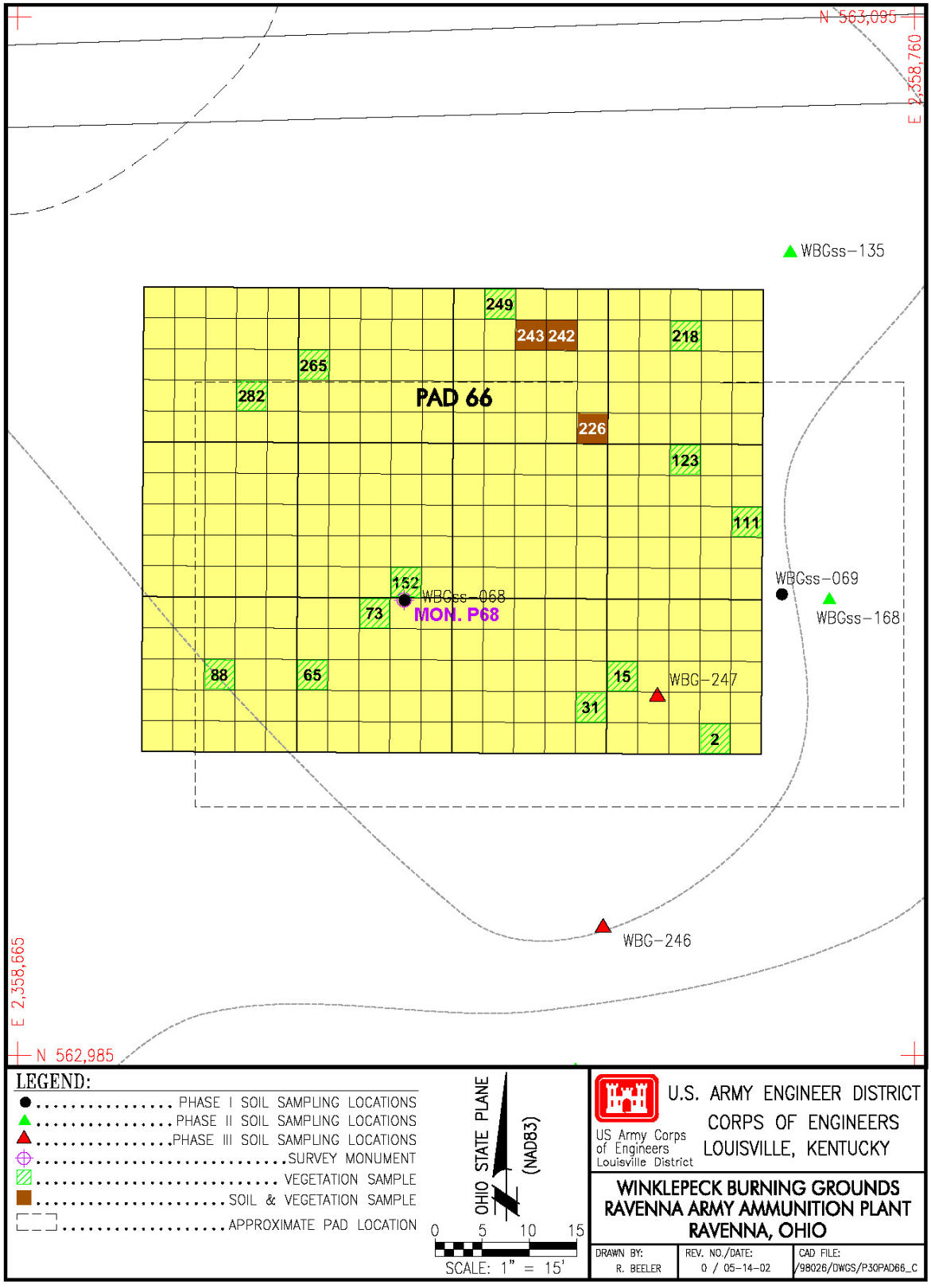

Figure 4-12. Pad 66 Sample Locations: Blowup

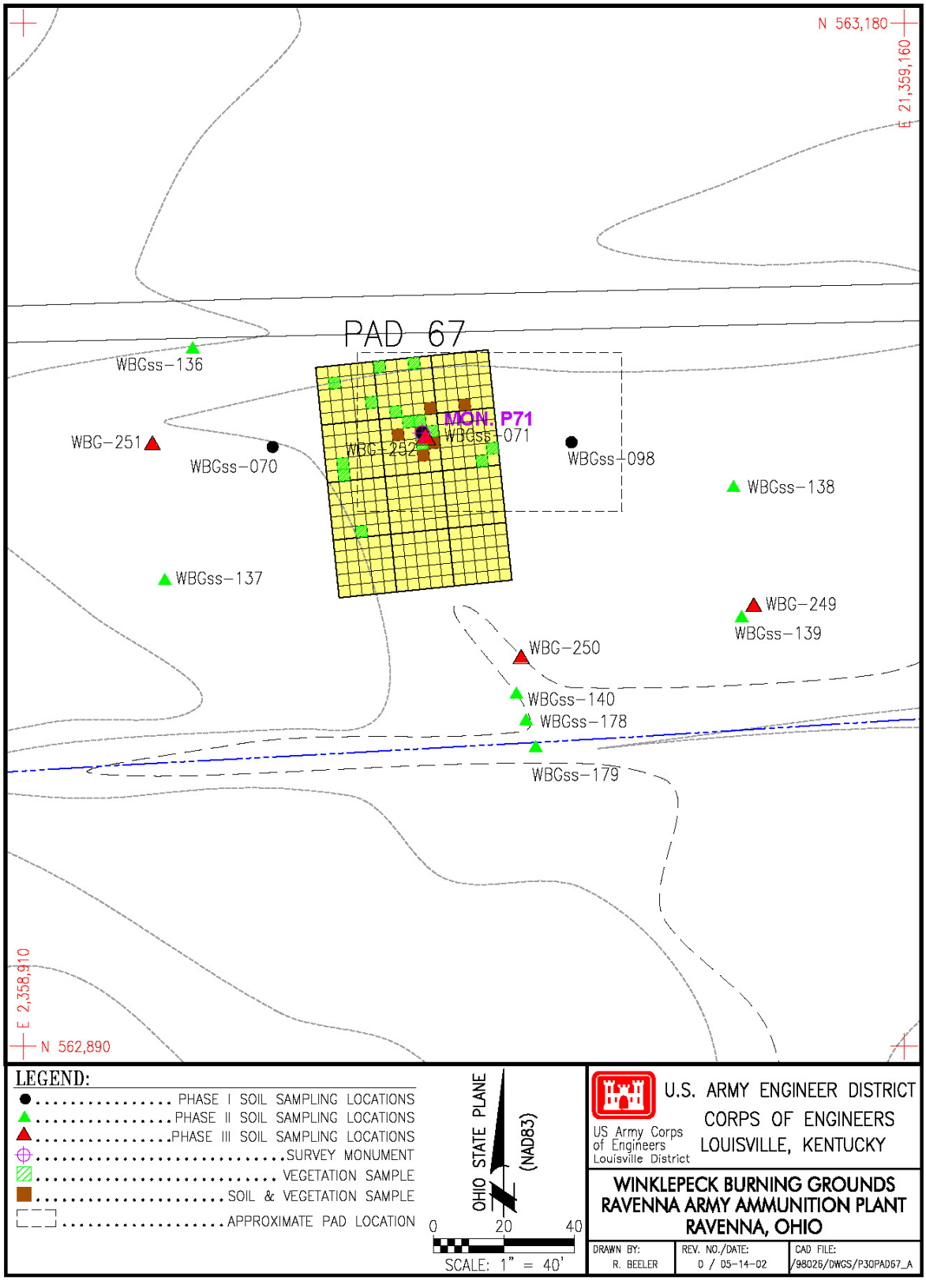

Figure 4-13. Pad 67 Sample Locations

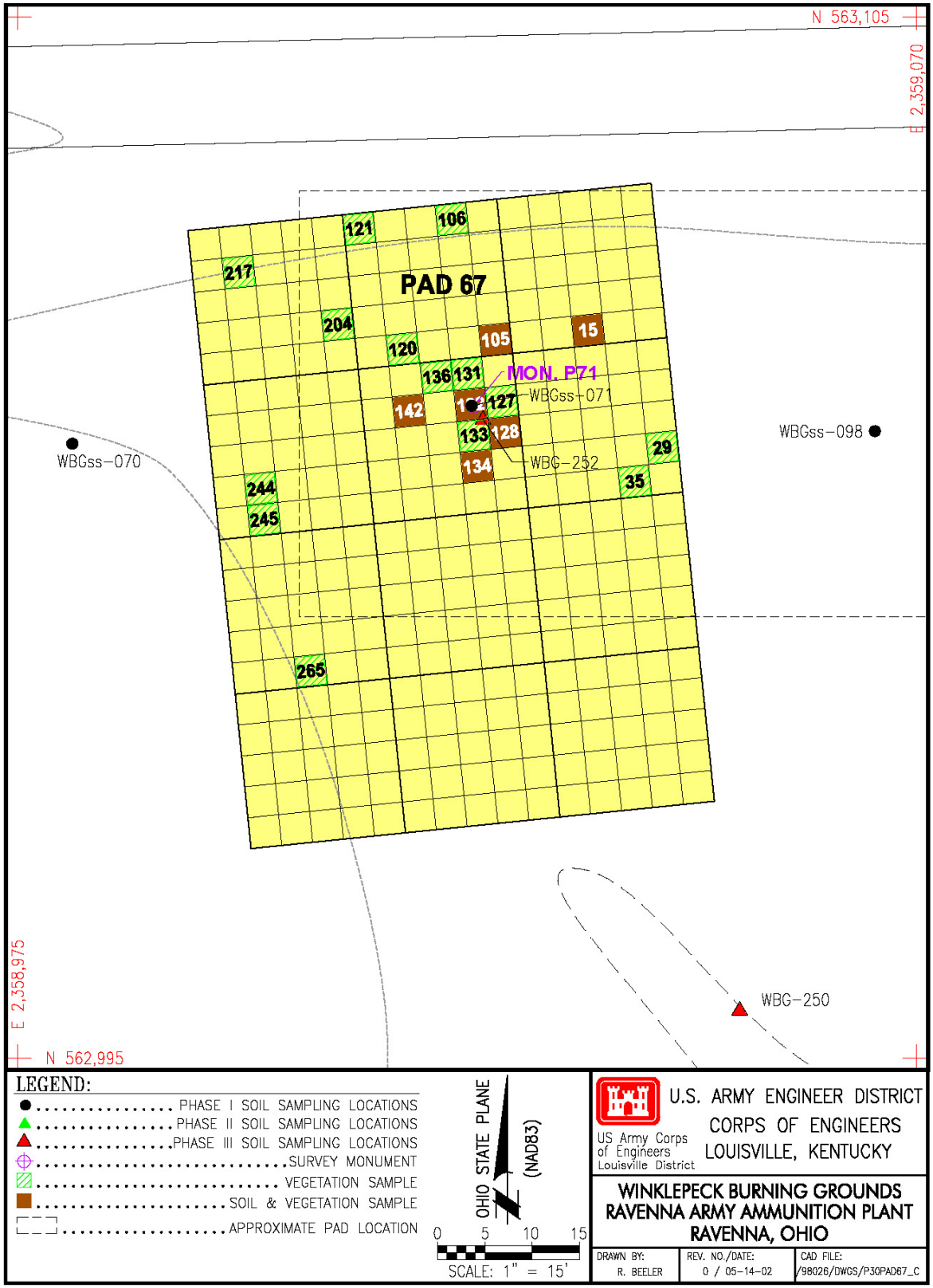

Figure 4-14. Pad 67 Sample Locations: Blowup

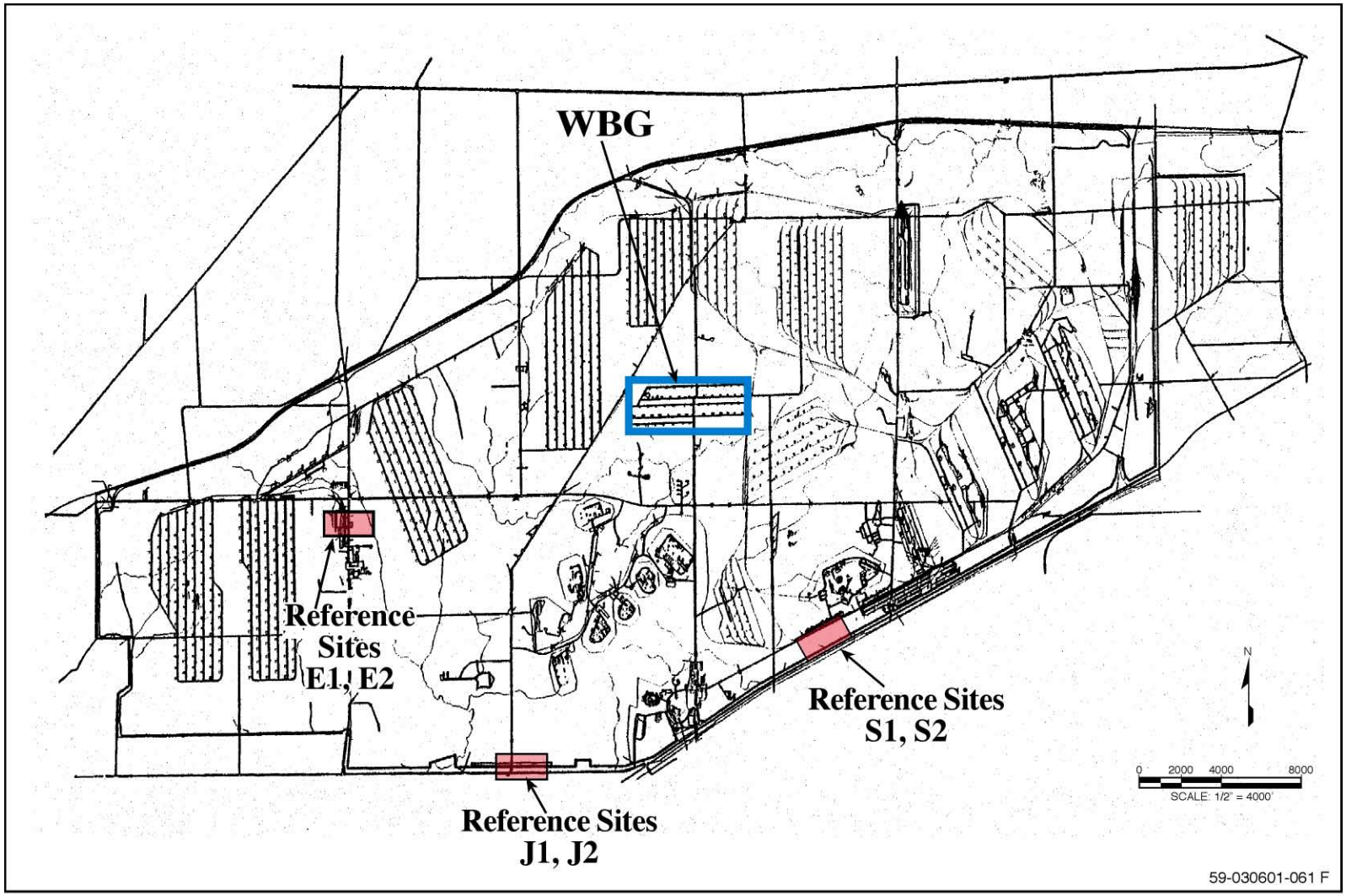

Figure 4-15. WBG and Reference Sites at RVAAP

TABLES

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Table 4-1. Percent Cover and Random Status of Soil Sample Plots

Pad 37			Pad 38			Pad 58			Pad 59			Pad 66			Pad 67		
Plot	Percent Cover	Status	Plot	Percent Cover	Status	Plot	Percent Cover	Status	Plot	Percent Cover	Status	Plot	Percent Cover	Status	Plot	Percent Cover	Status
236	17	NR	154	7	R	104	34	NR	253	39	NR	243	39	NR	132	0	NR
265		R	126	27	R	251	40	NR	108	100	R	242	84	NR	128	6	NR
130	75	NR	30	67	R	234/235	50	NR	140	100	R	226	100	R	134	11	NR
11	85	R	135	69	R	156	54	NR							142	30	R
			295	93	R	158	70	R							105	61	NR
						45	96	R							15	100	R

NR = Nonrandom.
R = Random.

Table 4-2. Sampling and Analytical Requirements

Parameter	Methods	Field Samples	Field Duplicate Samples	Site Source Water	Sample Rinsates	Trip Blanks	Total Samples	USACE Split Samples	Ohio EPA Split Samples
Soils									
SVOCs, TCL	SW-846, 8270C	27	3	1	-	-	31	2	-
Metals, TAL	SW-846, 6010B/7471	27	3	1	-	-	3	2	-
Cyanide	SW-846, 9011/9010	27	3	1	-	-	31	2	-
Explosives	SW-846, 8330	27	3	1	-	-	31	2	-
IDW – Decontamination Water									
TCLP (Full)	SW-846, 1311	1	-	-	-	-	1	-	-

EPA = U.S. Environmental Protection Agency.
IDW = Investigation-derived Waste.
SVOC = Semivolatile Organic Compound.
TAL = Target Analyte List.
TCL = Target Compound List.
TCLP = Toxicity Characteristic Leaching Procedure.
USACE = U.S. Army Corps of Engineers.

Table 4-3. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 37/38

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Inorganics (mg/kg)						
Aluminum	9/ 9	15500	13400	18800	17700	Yes
Antimony	2/ 9	1.23	0.84	6.1	0.96	Yes
Arsenic	9/ 9	12.8	9.1	16.5	15.4	Yes
Barium	9/ 9	79.6	56.2	124	88.4	Yes
Beryllium	8/ 9	0.634	0.44	1.6	0.88	Yes
Cadmium	9/ 9	2.33	0.6	6.7	(0.6)	NA
Calcium	9/ 9	15400	2710	47500	15800	Yes
Chromium	9/ 9	17.5	14.4	20.2	17.4	Yes
Cobalt	9/ 9	8.3	6.7	10.6	10.4	Yes
Copper	9/ 9	70.7	10.5	491	17.7	Yes
Cyanide	2/ 9	0.617	0.71	2.8	(0.6)	NA
Iron	9/ 9	26300	19200	31800	23100	Yes
Lead	9/ 9	29.1	15	56.8	26.1	Yes
Magnesium	9/ 9	4360	3010	8580	3030	Yes
Manganese	9/ 9	609	388	953	1450	No
Mercury	9/ 9	0.0401	0.028	0.052	0.04	Yes
Nickel	9/ 9	16	12.5	23.9	21.1	Yes
Potassium	9/ 9	1540	1150	2100	927	Yes
Selenium	8/ 9	1.12	0.72	1.5	1.40	Yes
Sodium	9/ 9	189	59.3	507	123	Yes
Thallium	9/ 9	0.459	0.39	0.51	(0.6)	NA
Vanadium	9/ 9	23.5	17.7	27.9	31.1	No
Zinc	9/ 9	110	51.4	346	61.8	Yes
Explosives (mg/kg)						
1,3,5-Trinitrobenzene	2/ 9	0.183	0.15	0.62	-	NA
1,3-Dinitrobenzene	1/ 9	0.121	0.088	0.088	-	NA
2,4,6-Trinitrotoluene	6/ 9	67	0.061	580	-	NA
2,4-Dinitrotoluene	3/ 9	0.133	0.063	0.21	-	NA
4-Nitrotoluene	1/ 9	0.132	0.19	0.19	-	NA
HMX	1/ 9	0.242	0.18	0.18	-	NA
RDX	2/ 9	0.277	0.32	0.42	-	NA

Table 4-3. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 37/38 (continued)

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Other Organics (mg/kg)						
2,4-Dinitrotoluene	5/ 9	2.35	0.09	19	-	NA
2,6-Dinitrotoluene	2/ 9	0.369	0.1	1.3	-	NA
2-Methylnaphthalene	1/ 9	0.488	0.069	0.069	-	NA
Di-n-butyl phthalate	5/ 9	3.48	0.078	26	-	NA
N-Nitrosodiphenylamine	2/ 9	0.392	0.66	1.5	-	NA
Phenanthrene	2/ 9	0.47	0.052	0.052	-	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of the 95% upper tolerance limit (UTL) of the 95th percentile of the surface soil background concentrations or the maximum detect. Values in parentheses are detection limits for metals that were not detected in the background study. Organic compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-terazocine.
NA = No background 95% UTL for comparison.
RMX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-4. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 58/59

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Inorganics (mg/kg)						
Aluminum	9/ 9	13100	5920	20000	17700	Yes
Antimony	6/ 9	9.13	0.64	64.7	0.96	Yes
Arsenic	9/ 9	11.2	5.7	14.6	15.4	No
Barium	9/ 9	125	50.3	453	88.4	Yes
Beryllium	5/ 9	0.387	0.5	0.57	0.88	No
Cadmium	9/ 9	2.69	0.22	9.2	(0.6)	NA
Calcium	9/ 9	11600	1080	28600	15800	Yes
Chromium	9/ 9	21.3	8.8	41.6	17.4	Yes
Cobalt	9/ 9	11.7	8.4	21.7	10.4	Yes
Copper	9/ 9	100	9.6	526	17.7	Yes
Iron	9/ 9	24200	13400	28700	23100	Yes
Lead	9/ 9	371	6.4	2800	26.1	Yes
Magnesium	9/ 9	4110	1700	7280	3030	Yes
Manganese	9/ 9	378	246	582	1450	No
Mercury	9/ 9	0.0597	0.024	0.17	0.04	Yes
Nickel	9/ 9	24.4	17.2	34.2	21.1	Yes
Potassium	9/ 9	1910	797	2950	927	Yes
Selenium	9/ 9	1.33	0.53	2.1	1.40	Yes
Silver	4/ 9	1.31	0.61	6.4	(1.2)	NA
Sodium	7/ 9	185	75.7	451	123	Yes
Thallium	9/ 9	0.454	0.34	0.51	(0.6)	NA
Vanadium	9/ 9	20.6	8.8	29.2	31.1	No
Zinc	9/ 9	234	31.5	838	61.8	Yes
Explosives (mg/kg)						
2,4,6-Trinitrotoluene	1/ 9	0.13	0.17	0.17		
RDX	2/ 9	0.288	0.18	0.66		
Other Organics (mg/kg)						
2-Methylnaphthalene	4/ 9	0.269	0.067	0.67		
Benz(a)anthracene	1/ 9	0.18	0.089	0.089		
Benzo(a)pyrene	2/ 9	0.169	0.04	0.14		
Benzo(b)fluoranthene	2/ 9	0.177	0.054	0.2		
Benzo(g,h,i)perylene	1/ 9	0.183	0.12	0.12		
Benzo(k)fluoranthene	1/ 9	0.177	0.065	0.065		
Bis(2-ethylhexyl) phthalate	2/ 9	0.178	0.13	0.14		

Table 4.4. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 58/59 (continued)

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Chrysene	1/ 9	0.182	0.11	0.11		
Dibenzofuran	1/ 9	0.174	0.045	0.045		
Fluoranthene	3/ 9	0.15	0.045	0.1		
Indeno(1,2,3-cd) pyrene	1/ 9	0.186	0.14	0.14		
Naphthalene	4/ 9	0.16	0.041	0.18		
Phenanthrene	4/ 9	0.172	0.054	0.27		
Pyrene	2/ 9	0.169	0.075	0.11		

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of 95% upper tolerance limit (UTL) of the 95th percentile of the surface soil background concentrations or the maximum detect. Values in parentheses are detection limits for metals that were not detected in the background study. Organic and explosive compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
NA = No background 95% UTL for comparison.
RMX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-5. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 66/67

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Inorganics (mg/kg)						
Aluminum	9/ 9	13100	10600	16500	17700	No
Antimony	9/ 9	5.91	1	12.5	0.96	Yes
Arsenic	9/ 9	11.5	8.4	15.5	15.4	Yes
Barium	9/ 9	997	197	2090	88.4	Yes
Beryllium	9/ 9	0.459	0.39	0.52	0.88	No
Cadmium	9/ 9	2.43	0.63	8.7	(0.6)	NA
Calcium	9/ 9	7550	4710	10000	15800	No
Chromium	9/ 9	19.5	15.5	24.3	17.4	Yes
Cobalt	9/ 9	6.92	4.9	8.4	10.4	No
Copper	9/ 9	115	31.6	269	17.7	Yes
Cyanide	8/ 9	1.03	0.6	1.8	(0.6)	NA
Iron	9/ 9	24600	18600	29600	23100	Yes
Lead	9/ 9	108	38.2	290	26.1	Yes
Magnesium	9/ 9	2980	2420	3480	3030	Yes
Manganese	9/ 9	715	578	888	1450	No
Mercury	9/ 9	0.117	0.059	0.29	0.04	Yes
Nickel	9/ 9	15.3	13.3	17.7	21.1	No
Potassium	9/ 9	1410	877	1640	927	Yes
Selenium	9/ 9	1.15	0.6	1.7	1.40	Yes
Silver	1/ 9	0.558	0.22	0.22	(1.2)	NA
Sodium	7/ 9	161	88.6	178	123	Yes
Thallium	9/ 9	0.468	0.43	0.49	(0.6)	NA
Vanadium	9/ 9	22.3	16.1	29.2	31.1	No
Zinc	9/ 9	245	83.7	624	61.8	Yes
Explosives (mg/kg)						
1,3,5-Trinitrobenzene	7/ 9	17	0.89	39		
1,3-Dinitrobenzene	3/ 9	0.101	0.042	0.071		
2,4,6-Trinitrotoluene	9/ 9	629	0.32	2000		
2,4-Dinitrotoluene	4/ 9	0.181	0.085	0.25		
4-Nitrotoluene	1/ 9	0.13	0.17	0.17		
HMX	9/ 9	115	0.36	370		
RDX	9/ 9	730	0.19	2400		
Other Organics (mg/kg)						
2,4-Dinitrotoluene	3/ 9	1.37	0.26	1.5		
2-Methylnaphthalene	1/ 9	1.57	0.051	0.051		
Acenaphthene	1/ 9	1.59	0.22	0.22		
Anthracene	1/ 9	1.66	0.87	0.87		
Benz(a)anthracene	2/ 9	1.77	0.21	2.6		
Benzo(a)pyrene	1/ 9	1.82	2.3	2.3		
Benzo(b)fluoranthene	2/ 9	1.8	0.29	2.8		

Table 4-5. Summary of Analytes Detected in Collocated Soil Samples at Winklepeck Burning Grounds at Pads 66/67 (continued)

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Benzo(g,h,i)perylene	1/ 9	1.68	1.1	1.1		
Benzo(k)fluoranthene	1/ 9	1.68	1.1	1.1		
Carbazole	1/ 9	1.61	0.41	0.41		
Chrysene	1/ 9	1.82	2.3	2.3		
Dibenz(a,h)anthracene	1/ 9	1.6	0.34	0.34		
Dibenzofuran	1/ 9	1.58	0.19	0.19		
Fluoranthene	3/ 9	1.93	0.35	5.3		
Fluorene	1/ 9	1.59	0.29	0.29		
Indeno(1,2,3-cd)pyrene	1/ 9	1.72	1.4	1.4		
Naphthalene	1/ 9	1.57	0.074	0.074		
Phenanthrene	1/ 9	1.92	3.2	3.2		
Pyrene	2/ 9	2.02	0.35	4.7		

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of 95% upper tolerance limit (UTL) of the 95th percentile of the surface soil background concentrations or the maximum detect. Values in parentheses are detection limits for metals that were not detected in the background study. Organicand explosive compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-terazocine.
NA = No background 95% UTL for comparison.
RMX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-6. Distribution of Soil Samples Relative to Vegetation Sampling Grid

Location	RI/FS			Biological Ground-truthing Soil/Plants	Total Samples
	Phase I	Phase II	Phase III		
Pad 37					
Inside Grid	1	0	0	4	5
Outside Grid	2	5	5	--	12
Pad 38					
Inside Grid	2	0	1	5	8
Outside Grid	0	3	3	--	6
Pad 58					
Inside Grid	1	4	1	6	12
Outside Grid	0	1	7	--	8
Pad 59					
Inside Grid	2	1	0	3	6
Outside Grid	0	4	9	--	13
Pad 66					
Inside Grid	1	0	1	3	5
Outside Grid	1	6	3	--	10
Pad 67					
Inside Grid	1	0	1	6	8
Outside Grid	2	7	3	--	12
Total Samples	13	31	34	27	105

RI/FS = Remedial Investigation/Feasibility Study.

Table 4-7. Geographic Distribution of Pad 37 Metals and Explosives Concentrations in Surface Soil, b y Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad					Inside Pad/Outside Grid				Outside Grid/ Outside Pad
			Phase I 030	Eco Study 236	Eco Study 265	Eco Study 130	Eco Study 11	Phase I 032	Phase II 153	Phase II 154	Phase III 223	Highest Concentration Among Samplesa*
Metals												
Cyanide	0	*0.51*		2.8	0.28	0.30	0.29		0.25	0.25		**0.34**
Aluminum	17,700	17,661	12,300	18,800	17,000	15,700	15,900	30,400	29,200	**30,700**	17,700	22,500
Antimony	0.96	*1.5*		**6.1**	1.1	1.2	0.84		0.5	0.4	1.2	2.8
Arsenic	15.4	11.1	17.7	10	11.8	13.1	13.3	2.5	0.31	0.59	10.3	**25.6**
Barium	88.4	*165*	65.8	124	78.4	72.9	83.7	466	**495**	301	267	250
Beryllium	0.88	*2.1*		1.6	0.51	0.44	0.45		7.8	**10.9**	1.8	2.6
Cadmium	0	*4.1*	0.58	1.3	0.87	0.6	0.88	**26.8**	0.25	0.25	6.9	15.9
Calcium	15,800	*52,862*		47,500	11,700	2,710	4,910		228,000	**247,000**	39,000	111,000
Chromium	17.4	*20.1*	17.8	16	20	20.2	19.7	**37.6**	27.3	3.4	30.2	30.8
Cobalt	10.4	7.2		6.9	6.7	9.5	8.6		7.5	0.92	6.9	**11.5**
Copper	17.7	*51.9*		17.6	**491**	19.1	15.3		1.7	0.32	16.2	59
Iron	23,100	20,083		21,500	26,100	29,600	25,000		1,350	2,720	20,000	**30,600**
Lead	26.1	*159*	108	56.8	25.9	21.6	52.7	23.8	5.6	0.15	28.4	**1490**
Magnesium	3,030	*11,487*		8,580	3,930	3020	3410		**53,700**	49,700	10000	16,700
Manganese	1,450	1,200	351	953	552	668	508	2,580	**4,270**	1,190	1020	3150
Mercury	0.04	0.03	0.02	0.033	0.038	0.043	**0.052**	0.02	0.05	0.05	0.017	.046
Nickel	21.1	14		13.3	14.3	14.9	15.2		4	4	12	**22.6**
Potassium	927	*1,772*		2,100	1,800	1,680	1,770		**3,710**	1,920	1,580	2230
Selenium	1.4	1.0	0.62	1	0.94	1.2	0.72	**2.4**	1.5	2	1.4	1.3
Silver	0	*0.6*	0.11	0.6	0.55	0.6	0.6	**1.5**	0.5	0.5	0.51	0.7
Sodium	123	*533*		507	162	59.3	106		**2320**	1770	366	997
Thallium	0	*0.5*		0.47	0.46	0.49	0.51		0.5	0.25	0.26	**2.7**
Vanadium	31.1	22		21	27.9	27.4	26.1		23.2	4.9	24	**31**
Zinc	61.8	*129*	133	85.9	**346**	61.2	62.7	315	4.7	1	128	248
Explosives												
1,3,5-Trinitro-benzene		0.1										0.140
1,3-Dinitro-benzene		0.1										
2,4,6, Trinitro-toluene		0.4		0.110		0.068						1.900
2,4-Dinitro-toluene		0.2	0.250		0.170			0.250				0.300

Table 4-7. Geographic Distribution of Pad 37 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad					Inside Pad/Outside Grid				Outside Grid/ Outside Pad
			Phase I 030	Eco Study 236	Eco Study 265	Eco Study 130	Eco Study 11	Phase I 032	Phase II 153	Phase II 154	Phase III 223	Highest Concentration Among Samples*
2,6-Dinitro-toluene		0.1										
2-Nitro-toluene		0.1										
3-Nitro-toluene		0.1										0.120
4-Nitro-toluene		0.1										0.190
HMX		0.6		0.180								1.200
Nitro-benzene		0.1										0.054
Nitro-cellulose		246	NA	NA	NA	NA	NA	NA			NA	315.000
Nitro-glycerin		3.1	NA					NA				12.000
Nitro-guanidine		0.2	NA	NA	NA	NA	NA	NA			NA	0.250
RDX		1.2		0.420								6.500

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase I samples (031 and 033), Phase II samples (106, 107, 175, and 187), and Phase III (Feasibility Study) samples (224, 225, 226, and 227) are located outside grid/outside pad. The last column on the table lists the highest concentrations from these samples for each chemical.
Bold number = highest concentration measured. **Bold analyte name** = mean value is greater than facility-wide surface soil background.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-8. Geographic Distribution of Pad 38 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad						Inside Pad/ Outside Grid	Inside Grid/ Outside Pad		Outside Grid/ Outside Pad
			Phase I 034	Phase I 035	Eco Study 126	Eco Study 030	Eco Study 135	Eco Study 154	Phase III 231	Eco Study 295	Phase III 232	Highest Concentration Among These Samples*
Metals												
Cyanide	0	*0.37*	*NA	NA	*0.29	0.29	***0.71**	0.58	NA	0.3	NA	0.34
Aluminum	17,700	14,792	15,300	**22,200**	13,900	13,400	15,700	13,800	13,300	15,400	11,500	20,300
Antimony	0.96	*1.15*	*NA	NA	1.2	1.2	1.1	1.2	**2.2**	1.2	1.2	1.3
Arsenic	15.4	12.8	10.5	7.1	14.9	13.4	9.1	16.5	**17.8**	13.5	12.6	16.1
Barium	88.4	*146.5*	**596**	255	62.4	56.2	108	60.3	203	70.3	112	136
Beryllium	0.88	0.58	NA	NA	0.18	0.44	1	0.61	0.31	0.48	0.67	**1.6**
Cadmium	0	*80.7*	**877**	63.4	1.9	6.1	6.7	1.9	43.6	0.68	31.6	13.2
Calcium	15,800	13,244	NA	NA	3,790	7,800	40,700	9,180	3,810	10,100	17,000	**56,400**
Chromium	17.4	*18.9*	26.6	**27.2**	16.8	15.9	14.4	17.1	26.3	17.3	14.4	21.9
Cobalt	10.4	8.1	NA	NA	10	8.1	6.9	10.6	**10.1**	7.4	7.9	9.4
Copper	17.7	*23.9*	NA	NA	20.2	20.1	17.9	24.3	29.7	10.5	18.9	**82**
Iron	23,100	*24,191*	NA	NA	27,800	27,500	19,200	31,800	**28,700**	28,400	21,900	28,600
Lead	26.1	*114.1*	**504**	236	18.8	21.4	30.2	19.8	223	15	37.4	300
Magnesium	3,030	*3,679*	NA	NA	3,010	3,370	6,840	3,910	2,650	3,140	4,000	**8,220**
Manganese	1,450	798	1,480	**2,170**	442	433	844	388	467	696	829	1,240
Mercury	0.04	*0.11*	0.015	0.015	0.04	0.037	**0.941**	0.028	0.023	0.049	0.027	0.065
Nickel	21.1	17.3	NA	NA	19.6	17.7	12.9	23.9	**22.1**	12.5	18.3	21.2
Potassium	927	*1168*	NA	NA	1390	1150	1240	1340	951	1430	928	**1,670**
Selenium	1.4	1.4	**5**	1.4	1.3	1.2	0.92	1.3	2.5	1.5	0.29	1.1
Silver	0	*0.55*	0.1	0.19	0.6	0.6	0.55	1.2	0.65	0.6	0.6	0.65
Sodium	123	*197*	NA	NA	291	73.1	312	113	127	81	184	**637**
Thallium	0	*0.48*	NA	NA	0.49	0.43	0.42	0.39	0.43	0.47	0.43	**0.67**
Vanadium	31.1	22.1	NA	NA	22.4	20.5	17.7	20.3	25.6	27.9	16.3	**29.6**
Zinc	61.8	*192.3*	342	316	72	106	119	88.7	287	51.4	73.1	**877**
Explosives												
1,3,5-Trinitro-benzene		0.2	*	0.250			0.150	0.620				0.057
1,3-Dinitro-benzene		0.1		0.250			0.088					
2,4,6, Trinitro-toluene		67.3		2.800	6.200	0.061	16.000	580.000			0.066	
2,4-Dinitro-toluene		0.2	0.310	0.250			0.210	0.063			0.150	
2,6-Dinitro-toluene		0.1		0.260								
2-Nitro-toluene		0.1		0.250								

Table 4-8. Geographic Distribution of Pad 38 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad						Inside Pad/ Outside Grid	Inside Grid/ Outside Pad		Outside Grid/ Outside Pad
			Phase I 034	Phase I 035	Eco Study 126	Eco Study 030	Eco Study 135	Eco Study 154	Phase III 231	Eco Study 295	Phase III 232	Highest Concentration Among These Samples*
3-Nitro-toluene		0.1		0.250								
4-Nitro-toluene		0.1		0.250						0.190		
HMX		0.4										
Nitro-benzene		0.3		0.260								
Nitro-cellulose		2.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.000
Nitro-glycerin		1.3	NA	NA								
Nitro-guanidine		0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.250
RDX		0.4		1.000		0.320						

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase II samples (108, 109, and 110) and Phase III (Feasibility Study) samples 229 and 230 are located outside grid/outside pad. The last column on the table lists the highest concentrations from these samples for each chemical.
Bold number = highest concentration measured. **Bold analyte name =** mean value is greater than facility-wide surface soil background.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-9. Geographic Distribution of Pad 58 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean	Inside Grid/Inside Pad											Outside Grid/ Inside Pad	Inside Grid/ Outside Pad	Outside Grid/ Outside Pad
			Phase I 054	Phase I 114	Phase I 115	Phase II 170	Phase II 171	Eco Study 104	Eco Study 156	Eco Study 158	Eco Study 234/235	Eco Study 251	Phase III 203	Phase II 116	Eco Study 045	Highest Concentration Among Samples*
Metals																
Cyanide	0	*0.28	*NA	*0.3	0.3	0.35	0.31	0.29	0.29	0.29	0.29	0.28		0.064	0.29	
Aluminum	17,700	12,245	12,500	10,300	11,700	9,530	14,000	11,200	12,700	12,500	13,400	11,200	12,800	***17,700**	5,920	16,100
Antimony	0.96	5.8	NA	3.3	1.3	12.9	2.9	1.2	1.7	1.5	1.1	0.66	0.74	6.1	1.1	**49.8**
Arsenic	15.4	14.5	19	15.9	14.1	23.5	14.3	14.6	11.5	14.3	11.2	11.5	11.9	16.9	5.7	**33.5**
Barium	88.4	115.7	174	102	87.2	204	101	90	63	92.2	61.3	60.8	109	149	50.3	**386**
Beryllium	0.88	0.53	NA	0.59	0.6	0.62	0.43	0.51	0.51	0.51	0.5	0.47	0.71	**0.81**	0.56	0.75
Cadmium	0	5.8	4.6	**80**	1.1	14	1	5.3	0.55	1	0.53	0.5	0.75	1.4	0.22	1.7
Calcium	15,800	9,049	NA	3,220	17,500	13,500	3,870	1,830	18,400	14,000	**28,600**	28,200	2,480	8,820	1,080	14,500
Chromium	17.4	30.9	29.3	**189**	19.3	46.4	23.7	16	17.7	22.1	17.8	15.6	19	31.3	8.8	47.7
Cobalt	10.4	10.6	NA	11.2	11.2	7.8	8.4	10.1	9.5	11.3	9.9	9.3	11.4	12.7	**21.7**	13.9
Copper	17.7	129.7	NA	252	46.9	**653**	138	36.3	20.8	50.4	19.3	24.2	28.3	109	9.6	469
Iron	23,100	26,437	NA	26,500	29,800	21,500	25,100	25,900	25,300	28,700	24,200	23,700	25,100	32,800	13,400	**46,400**
Lead	26.1	174	202	**1020**	38.9	385	89.4	13.8	12.3	54.3	25.7	11.6	16	122	6.4	922
Magnesium	3,030	3,822	NA	2,940	5,260	3,080	2,810	3,070	5,050	5,410	7,280	**5,770**	3650	5,170	1,700	5440
Manganese	1,450	491	575	480	453	522	436	335	362	390	343	352	366	453	246	**1370**
Mercury	0.04	0.30	0.21	0.3	0.089	1.1	0.32	0.062	0.2	0.17	0.024	0.033	0.04	0.22	0.025	**1.4**
Nickel	21.1	26.0	NA	32.1	29.8	25.4	24.1	27.3	24.3	26.9	24.1	22	35.9	37.2	17.2	**38.9**
Potassium	927	1,734	NA	1,330	1,660	1,080	1,550	1,810	2,600	2,270	**2,950**	2,110	2,300	2,670	797	2300
Selenium	1.4	1.1	1.3	0.61	0.61	0.39	0.32	1.3	1.2	1.6	1.2	1.1	0.29	0.71	0.53	**2.4**
Silver	0	2.1	6.4	1.4	1.2	5.8	1.9	0.6	0.6	0.96	0.55	0.55	0.6	3.0	0.55	**9.5**
Sodium	123	279	NA	92.8	78.8	223	76.2	289	94.8	76.9	86.9	75.7	80.6	111	287	**626**
Thallium	0	0.6	NA	0.61	0.61	0.35	0.47	0.5	0.48	0.49	0.4	0.46	0.53	0.71	0.47	**0.8**
Vanadium	31.1	20.2	NA	17.6	20.1	15.1	23.9	18.3	20.2	21.3	21.5	17.6	21.7	**27.9**	8.8	27.2
Zinc	61.8	495	604	813	215	863	485	106	77.4	146	56.2	58.7	88.6	458	31.5	**4520**
1,3,5-Trinitro-benzene		0.1	*													
1,3-Dinitro-benzene		0.1														
2,4,6, Trinitro-toluene		0.1														
2,4-Dinitro-toluene		0.1														
2,6-Dinitro-toluene		0.1														

Table 4-9. Geographic Distribution of Pad 58 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean	Inside Grid/Inside Pad											Outside Grid/ Inside Pad	Inside Grid/ Outside Pad	Outside Grid/ Outside Pad
			Phase I 054	Phase I 114	Phase I 115	Phase II 170	Phase II 171	Eco Study 104	Eco Study 156	Eco Study 158	Eco Study 234/235	Eco Study 251	Phase III 203	Phase II 116	Eco Study 045	Highest Concentration Among Samples*
2-Nitro-toluene		0.1														
3-Nitro-toluene		0.1														
4-Nitro-toluene		0.1														
HMX		0.3														
Nitro-benzene		0.1														
Nitro-cellulose		2.0	NA					NA	NA	NA	NA	NA	NA	**2.000**	NA	NA
Nitro-glycerin		1.1	NA													
Nitro-guanidine		0.3	NA					NA	NA	NA	NA	NA	NA	**0.250**	NA	NA
RDX		0.3								**0.660**						

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase III (Feasibility Study) samples 197, 198, 199, 200, 201, 202, and 263 are located outside grid/outside pad.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Bold = highest concentration measured.
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-10. Geographic Distribution of Pad 59 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad					Inside Grid/ Outside Pad	Outside Grid/Outside Pad
			Phase I 055	Phase I 056	Eco Study 108	Eco Study 140	Eco Study 253	Phase I 117	Highest Concentration Among These Samples*
Metals									
Cyanide	0	*0.31*			0.29	0.29	0.30	*0.3	**0.35**
Aluminum	17,700	13,325	11,600	7,070	**20,000**	17,600	12,900	9,300	16,600
Antimony	0.96	*17.6*			64.7	10.5	2.5	0.6	**157**
Arsenic	15.4	11.8	12.1	7.4	9.4	12	10.5	10.4	**15.1**
Barium	88.4	*130.1*	96.1	43.1	453	160	87.8	36.3	**629**
Beryllium	0.88	0.33			**0.58**	0.31	0.3	0.1	0.52
Cadmium	0	*1.7*	1.3	0.36	4.6	3.4	3.5	0.3	**7.5**
Calcium	15,800	2,662			9,150	3,230	2,210	1,290	**9190**
Chromium	17.4	*26.9*	**118**	11.5	41.6	33.4	18.5	11.7	50.6
Cobalt	10.4	9.5			9.4	**15.2**	8.4	7.1	12.5
Copper	17.7	*108.0*			**526**	166	51.7	17.3	177
Iron	23,100	*26,676*			24,300	28,100	24,200	17,500	**57,100**
Lead	26.1	*386*	916	39	**2800**	300	111	15.7	1690
Magnesium	3,030	2,602			2,990	3,250	2,340	1,720	**4110**
Manganese	1,450	451	405	177	582	417	362	373	**1630**
Mercury	0.04	*0.07*	0.02	0.02	0.055	0.056	0.078	0.026	**0.28**
Nickel	21.1	*23.0*			25.7	34.2	18.5	12.9	**50.7**
Potassium	927	*1,269*			1,650	1,830	1,170	753	**2040**
Selenium	1.4	0.76	1.1	0.17	**2.1**	1.8	1.4	0.3	1.4
Silver	0	*2.23*	0.54	0.22	6.4	1	0.61	0.6	**22.5**
Sodium	123	*304*			451	234	77.9	29	**638**
Thallium	0	*0.47*			0.34	0.46	0.46	0.3	**0.71**
Vanadium	31.1	24.4			24.7	29.2	23.2	16.6	**35.6**
Zinc	61.8	*446*	1040	91.1	838	605	203	56.9	**3330**
Explosives									
1,3,5-Trinitro-benzene		0.1							
1,3-Dinitro-benzene		0.1							
2,4,6, Trinitro-toluene		4.8	33.000			0.170			
2,4-Dinitro-toluene		01.							
2,6-Dinitro-toluene		0.1							
2-Nitro-toluene		0.1							
3-Nitro-toluene		0.1							
4-Nitro-toluene		0.1							
HMX		0.4						0.120	

Table 4-10. Geographic Distribution of Pad 59 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad					Inside Grid/ Outside Pad	Outside Grid/Outside Pad
			Phase I 055	Phase I 056	Eco Study 108	Eco Study 140	Eco Study 253	Phase I 117	Highest Concentration Among These Samples*
Nitrobenzene		0.1							
Nitrocellulose		2.0	NA	NA	NA	NA	NA	2.000	NA
Nitroglycerin		1.3	NA	NA					
Nitroguanidine		2.5	NA	NA	NA	NA	NA	2.500	NA
RDX		0.6				0.180			

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase II samples (118, 119, 169, and 172) and Phase III (Feasibility Study) samples 204–210 and 296–297 are located outside grid/outside pad. The last column on the table lists the highest concentrations from these samples for each chemical.
Bold number = highest concentration measured. **Bold analyte name =** mean value is greater than facility-wide surface soil background.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-11. Geographic Distribution of Pad 66 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad			Inside Grid/ Outside Pad		Outside Grid/ Inside Pad		Outside Grid/Outside Pad
			Phase I 068	Eco Study 226	Phase III 247	Eco Study 242	Eco Study 243	Phase I 069	Eco Study 168	Highest Concentration Among These Samples*
Metals										
Cyanide	0	*0.50*		0.30		0.60	**1.1**		0.78	0.62
Aluminum	17,700	14,167	12,900	16,500	13,900	13,700	13,700	14,800	11,200	**18,100**
Antimony	0.96	*6.20*		1	45.1	2.7	1.2		**11.2**	6.3
Arsenic	15.4	13.6	11.7	15.5	13	12.4	11.8	15.6	15.1	**17.9**
Barium	88.4	*1,678*	176	197	1320	411	234	**7780**	698	7160
Beryllium	0.88	0.36		0.52	0.46	0.52	0.51		0.2	**0.62**
Cadmium	0	*2.6*	0.025	0.75	8.3	2.3	0.76	4.8	1.2	**15.7**
Calcium	15,800	7,947		4,710	3,350	9,510	8,560		12,100	**46,600**
Chromium	17.4	*30.5*	14.9	**195**	24	19.3	16.2	16.5	26.6	20.6
Cobalt	10.4	7.5		8.4	6.4	7	7.9		7.6	**12.6**
Copper	17.7	*343.1*		47.8	876	131	31.6		**1920**	926
Iron	23,100	*25,223*		29,600	23,400	25,800	24,200		27,400	**29,900**
Lead	26.1	*172.0*	17.5	38.2	336	290	69.1	289	**1010**	208
Magnesium	3,030	*3,035*		3,480	2200	3,410	3,410		3,330	**3970**
Manganese	1,450	690	358	682	635	684	681	784	799	**1800**
Mercury	0.04	*0.13*	0.02	0.073	0.12	0.075	0.059	0.28	0.052	**0.53**
Nickel	21.1	17.8		16.8	17.3	17.7	16		**21.3**	20.6
Potassium	927	*1,501*		1,640	1,980	1,440	1,330		1,360	**1830**
Selenium	1.4	1.00	0.18	1.4	0.37	1.4	1.4	0.18	0.31	**1.8**
Silver	0	*0.61*	0.12	0.6	0.21	0.55	0.6	0.33	**1.8**	0.7
Sodium	123	*133*		**298**	256	120	101		187	162
Thallium	0	*0.47*		0.46	0.55	0.44	0.49		0.31	**0.71**
Vanadium	31.1	23.8		29.2	22.6	20.8	22.4		17.6	**33.1**
Zinc	61.8	*450.9*	79	139	1410	259	83.7	1050	690	**1590**
Explosives										
1,3,5-Trinitro-benzene		15.3				1.900		76.000	28.000	0.150
1,3-Dinitro-benzene		6.3	0.250					12.500		
2,4,6, Trinitro-toluene		642.8	0.470	0.320		38.000	180.000	3800.000	480.000	0.950
2,4-Dinitro-toluene		2.0	0.250	0.085		0.180		12.500	0.550	
2,6-Dinitro-toluene		6.4							0.620	0.087
2-Nitro-toluene		5.4								
3-Nitro-toluene		4.0							21.000	
4-Nitro-toluene		5.4		0.170						
HMX		74.8		0.360		62.000	370.000		40.000	
Nitrobenzene		5.4								
Nitrocellulose		19.1	NA	NA	NA	NA	NA	NA	32.200	5.900
Nitroglycerin		2.0	NA					NA		

Table 4-11. Geographic Distribution of Pad 66 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad			Inside Grid/ Outside Pad		Outside Grid/ Inside Pad		Outside Grid/Outside Pad
			Phase I 068	Eco Study 226	Phase III 247	Eco Study 242	Eco Study 243	Phase I 069	Eco Study 168	Highest Concentration Among These Samples*
Nitroguanidine		0.3	NA	NA	NA	NA	NA	NA	0.250	0.250
RDX		410.8		0.190		370.000	2400.000		80.000	0.180

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase II samples (131, 132, 133, 134, and 135) and Phase III (Feasibility Study) samples 243, 245, and 246 are located outside grid/outside pad. The last column on the table lists the highest concentrations from these samples for each chemical.
Bold number = highest concentration measured. **Bold analyte name =** mean value is greater than facility-wide surface soil background.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-12. Geographic Distribution of Pad 67 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad								Outside Grid/Inside Pad	Outside Grid/ Outside Pad
			Phase I 071	Eco Study 015	Eco Study 105	Eco Study 128	Eco Study 132	Eco Study 134	Eco Study 142	Eco Study 252	Phase I 098	Highest Concentration Among These Samples*
Metals												
Cyanide	0	*0.73*		0.74	1.30	**1.80**	1.20	1.1	1.1			0.35
Aluminum	17,700	11,638	6,330	10,600	11,900	13,300	11,300	12,300	14,400	7,700	11,000	**15,800**
Antimony	0.96	**4.5**		2.2	12.5	6.1	9.8	10	7.7	**14.6**		2.3
Arsenic	15.4	11.6	15.8	12.6	12.1	11.2	8.4	9.8	9.4	10.2	10.3	**16.4**
Barium	88.4	*1,004*	69.8	1520	1330	2050	714	2090	424	783	190	**2260**
Beryllium	0.88	0.39		0.42	0.44	0.44	0.42	0.39	0.47	0.46		**0.69**
Cadmium	0	*1.67*	0.07	1.6	4.3	8.7	0.96	1.9	0.63	0.86	0.14	**10**
Calcium	15,800	4,242		8,630	6,870	7,980	10,000	6,890	4,760	**11,700**		3170
Chromium	17.4	16.9	7	15.5	24.3	18.1	20.2	21.2	21.3	16.3	11.1	**25.1**
Cobalt	10.4	8.1		4.9	7.9	5.9	7.3	5.9	7.1	7		**18.2**
Copper	17.7	*91.4*		59.8	**269**	76.8	123	227	65.1	168		161
Iron	23,100	23,059		22,400	29,000	26,800	18,600	21,700	23,600	20,700		**32,200**
Lead	26.1	*55.9*	16.1	62.2	110	71.3	114	129	83.7	**147**	14.5	54.7
Magnesium	3,030	2,432		2,510	2,650	**3090**	2750	**3090**	2420	2750		2910
Manganese	1,450	713	165	674	773	888	719	752	578	762	389	**2020**
Mercury	0.04	*0.12*	0.13	0.29	0.12	0.19	0.077	0.088	0.082	0.038	0.04	**0.4**
Nickel	21.1	15.6		13.3	16.7	14.7	14.1	14.3	14.3	12.7		**33.1**
Potassium	927	*1,188*		877	1,460	1,410	1,470	1,480	**1,590**	944		1540
Selenium	1.4	0.79	0.17	1.3	0.94	**1.7**	0.69	0.95	0.6	0.05	0.18	1.6
Silver	0	*0.53*	0.11	0.6	0.6	0.65	0.6	0.22	0.6	0.6	0.11	0.7
Sodium	123	*142*		88.6	110	102	140	178	313	236		**646**
Thallium	0	*0.44*		0.49	0.46	0.49	0.48	0.47	0.43	0.57		**0.7**
Vanadium	31.1	22.9		16.1	21.8	24.2	18.5	20.8	27	14.7		**31.8**
Zinc	61.8	*180.8*	36.2	185	624	258	175	345	132	209	56.8	**624**
Explosives												
1,3,5-Trinitro-benzene				0.890	31.000	20.000	35.000	39.000	24.000	34.000		49.000
1,3-Dinitro-benzene			0.250		0.071			0.042	0.048	0.056		0.250
2,4,6, Trinitro-toluene			2.300	42.000	310.000	390.000	1400.000	1300.000	2000.000	430.000	0.280	3400.000
2,4-Dinitro-toluene			0.250	0.250		0.120					0.250	0.250
2,6-Dinitro-toluene												
2-Nitro-toluene												
3-Nitro-toluene												
4-Nitro-toluene												
HMX				25.000	160.000	44.000	230.000	85.000	62.000	100.000		1700.000

Table 4-12. Geographic Distribution of Pad 67 Metals and Explosives Concentrations in Surface Soil, by Sampling Location and Sampling Phase (continued)

Analyte	Surface Soil BG	Pad Mean*	Inside Grid/Inside Pad								Outside Grid/Inside Pad	Outside Grid/ Outside Pad
			Phase I 071	Eco Study 015	Eco Study 105	Eco Study 128	Eco Study 132	Eco Study 134	Eco Study 142	Eco Study 252	Phase I 098	Highest Concentration Among These Samples*
Nitrobenzene												0.350
Nitrocellulose			NA	NA	NA	NA	NA	NA	NA	NA	NA	2.500
Nitroglycerin			NA								NA	NA
Nitroguanidine			NA	NA	NA	NA	NA	NA	NA	NA	NA	0.250
RDX				200.000	940.000	190.000	1700.000	380.000	390.000	470.000		9500.000

*Notes: Left-adjusted numbers are nondetect; value shown is ½ detection limit.
NA = not analyzed.
Italics = mean value is greater than facility-wide surface soil background.
Phase I sample 070, Phase II samples (136–140 and 178–179) and Phase III (Feasibility Study) samples 249, 250, and 251 are located outside grid/outside pad. The last column on the table lists the highest concentrations from these samples for each chemical.
Bold number = highest concentration measured. **Bold analyte name =** mean value is greater than facility-wide surface soil background.
Blank (explosives) = nondetect (generally about 0.250 mg/kg).
Pad mean (explosives) based on estimated, measured, and ½ reporting limits.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-13. Comparison of Soil Concentrations Inside Grid Versus Outside Grid for Pads 37 and 38

Analyte	Inside Grids[a]					Outside Grids/Inside Pads[b]				Significantly Greater?[d]
	Results > Detection Limit	Average[c] Result	Maximum Detect	Dist.		Results > Detection Limit	Average[c] Result	Maximum Detect	Dist.	
Inorganics (mg/kg)										
Aluminum	13/ 13	15500	22200	L		9/ 9	19600	30700	L	No
Antimony	2/ 10	1.16	6.1	D		4/ 7	1.06	2.2	L	No
Arsenic	13/ 13	12.6	17.7	N		9/ 9	9.07	17.8	N	No
Barium	13/ 13	134	596	X		9/ 9	246	495	L	Outside
Beryllium	9/ 10	0.638	1.6	L		5/ 7	3.4	10.9	L	No
Cadmium	13/ 13	76.4	877	X		7/ 9	11.1	43.6	L	No
Calcium	10/ 10	15500	47500	L		7/ 7	88700	247000	L	No
Chromium	13/ 13	18.7	27.2	L		9/ 9	21.9	37.6	N	No
Cobalt	10/ 10	8.26	10.6	L		6/ 7	6.55	10.1	N	No
Copper	10/ 10	65.5	491	X		5/ 7	23.7	54.6	N	No
Cyanide	2/ 9	0.617	2.8	D		1/ 6	0.287	0.23	D	No
Iron	10/ 10	25900	31800	N		7/ 7	16200	28700	N	No
Lead	13/ 13	88.3	504	X		8/ 9	103	436	L	No
Magnesium	10/ 10	4320	8580	X		7/ 7	19300	53700	L	No
Manganese	13/ 13	793	2170	L		9/ 9	1450	4270	L	No
Mercury	10/ 13	0.0337	0.052	N		3/ 9	0.0297	0.03	D	Inside
Nickel	10/ 10	16.3	23.9	L		5/ 7	11.8	22.1	N	No
Potassium	10/ 10	1480	2100	L		7/ 7	1830	3710	L	No
Selenium	12/ 13	1.34	5	L		7/ 9	1.33	2.5	N	No
Sodium	8/ 10	180	507	L		3/ 7	770	2320	D	No
Thallium	10/ 10	0.456	0.51	N		3/ 7	0.686	2.7	D	Inside
Vanadium	10/ 10	22.8	27.9	L		7/ 7	20	28	N	No
Zinc	13/ 13	143	346	X		7/ 9	154	315	N	No
2,4,6-Trinitrotoluene	8/ 13	46.6	580	X		1/ 4	0.569	1.9	D	No
2,4-Dinitrotoluene	5/ 13	0.146	0.31	D		1/ 4	0.129	0.14	D	No

Table 4-13. Comparison of Soil Concentrations Inside Grid Versus Outside Grid for Pads 37 and 38 (continued)

Analyte	Inside Grids[a]					Outside Grids/Inside Pads[b]				Significantly Greater?[d]
	Results > Detection Limit	Average[c] Result	Maximum Detect	Dist.		Results > Detection Limit	Average[c] Result	Maximum Detect	Dist.	
HMX	1/ 13	0.418	0.18	D		1/ 4	0.903	0.61	D	No
RDX	2/ 13	0.326	0.42	D		2/ 4	2.48	6.5	L	Outside

[a]Samples considered inside the grid were the nine samples taken for this study plus samples from locations WBGss-030, WBGss-034, and WBGss-035 from the Winklepeck Burning Grounds (WBG) Phase I Remedial Investigation (RI) and location WBG-232 from the WBG Phase III sampling.
[b]Samples considered outside the grid but inside the pad were from locations WBGss-031, WBGss-032, and WBGss-033 from the WBG Phase I RI, locations WBGss-153, WBGss-154, WBGss-175, and WBGss-187 from the WBG Phase II RI, and locations WBG-223 and WBG-231 from the Phase III sampling.
[c]Averages include nondetects at one half the detection limit.
[d]Significance of difference determined by a two-tailed Wilcoxon rank sum test at probability $p < 0.05$.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 4-14. Study Sites and Reference Sites with Reference Site Descriptions

Burning Pads	Selected Reference Sites	Common Features of Burning Pads and Reference Sites	Reference Site Description
37 and 38	Reference Sites E1 and E2	Slag, recent disturbance, flat, used to store materials, created 1980 and last used 1992.	Old field hospital site, graded and covered with slag, adjacent to Building A-9, Portage Army Depot
58 and 59	Reference Sites S1 and S2	Little or no surface slag, flat and wet, bermed, shrubs and small trees adjacent, created 1941 and last used 1973.	Borrow pit off South Service Road near Load Line 4
66 and 67	Reference Sites J1 and J2	No surface slag or UXO, flat, herbaceous, created 1941 and last used no later than 1980.	Unpaved old air strip south of NACA test site

NACA = National Advisory Committee on Aeronautics.
UXO = unexploded ordnance.

Table 4-15. Sampling and Analytical Requirements for Reference Soil Samples

Parameter	Methods	Field Samples	Field Duplicate Samples	Site Source Water[a]	Rinsate Samples	Trip Blanks[b]	Total A-E Samples	USACE QA Split Samples	USACE Trip Blanks
Soil									
Volatile organics, TCL	SW-846, 5030/8260B	21	2	1	2	1	27	2	-
Semivolatile organics, TCL	SW-846, 3540/8270C	21	2	1	2	-	26	2	-
Pesticides, TCL	SW-846, 3540/8081A	21	2	1	2	-	26	2	-
PCBs, TCL	SW-846, 3540/8082	21	2	1	2	-	26	2	-
Explosives	SW-846, 8330	21	2	1	2	-	26	2	-
Propellants[a]	SW-846, 8330/9056	3	1	1	1	-	6	1	-
Metals, TAL	SW-846, 6010B/7471	21	2	1	2	-	26	2	-
Cyanide	SW-846, 9011/9012A	21	2	1	2	-	26	2	-

[a]Nitroguanidine, nitrocellulose, and nitroglycerine.
[b]Trip blanks will be included only with aqueous samples for volatile organic compound analyses.
A-E = Architect-Engineer.
PCBs = polychlorinated biphenyls.
QA = quality assurance.
TCL = Target Compound List.
USACE = U.S. Army Corps of Engineers.

Table 4-16. Summary of Facility-wide Background Soil Concentrations Using 11 and 15 Samples

Inorganic Analytes and Detected Organic Analytes	*11 Background Samples*							*15 Background Samples*				
	Number of Results > Detection Limit	Average[a]	Maximum Detect	95% UTL[b]	Dist.[c]	Facility-Wide Background Criteria[d]		Number of Results > Detection Limit	Average[a]	Maximum Detect	UTL[b]	Dist.[c]
Inorganics (mg/kg)												
Aluminum	11/ 11	10700	17700	22100	N	17700		15/ 15	12400	21600	24500	N
Antimony	0/ 11	(0.64)	ND	ND	D	0.96		1/ 15	0.362	1	1	D
Arsenic	11/ 11	10.5	15.4	20.2	L	15.4		15/ 15	9.62	15.4	18.4	L
Barium	11/ 11	65.2	88.4	112	L	88.4		15/ 15	95.9	222	222	X
Beryllium	0/ 11	(0.52)	ND	ND	D	0.88		4/ 15	0.625	2.5	2.5	X
Cadmium	0/ 11	(0.64)	ND	ND	D	NA		0/ 15	(0.64)	ND	ND	D
Calcium	11/ 11	4300	15800	97300	L	15800		15/ 15	18500	73300	620000	L
Chromium	11/ 11	12.1	17.4	24.2	N	17.4		15/ 15	12	17.4	21.9	N
Cobalt	11/ 11	7.53	10.4	14.2	N	10.4		15/ 15	6.87	10.4	15.6	L
Copper	11/ 11	11.5	17.7	17.7	X	17.7		15/ 15	12.7	21.3	21.3	X
Cyanide	0/ 11	(0.64)	ND	ND	D	NA		3/ 15	0.604	2.4	2.4	X
Iron	11/ 11	17200	23100	27600	N	23100		15/ 15	16200	23100	25700	N
Lead	11/ 11	18.4	26.1	32.8	L	26.1		15/ 15	23.9	66.5	66.5	X
Magnesium	11/ 11	1970	3030	4410	L	3030		15/ 15	3750	13200	13200	X
Manganese	11/ 11	638	1450	3050	L	1450		15/ 15	934	3060	4910	L
Mercury	7/ 11	0.0447	0.036	0.036	X	0.036		9/ 15	0.0443	0.05	0.102	L
Nickel	10/ 11	13.6	21.1	26	N	21.1		14/ 15	13.8	22.1	25.7	N
Potassium	11/ 11	621	927	1120	N	927		15/ 15	811	1730	2390	L
Selenium	2/ 11	0.452	1.4	1.4	X	1.4		2/ 15	0.415	1.4	1.4	D
Silver	0/ 11	(1.2)	ND	ND	D	NA		0/ 15	(1.2)	ND	ND	D
Sodium	1/ 11	42.8	123	123	D	123		5/ 15	125	450	450	X
Thallium	0/ 11	(0.64)	ND	ND	D	NA		0/ 15	(0.64)	ND	ND	D
Vanadium	11/ 11	19	31.1	40.8	N	31.1		15/ 15	17.8	31.1	45.9	L
Zinc	11/ 11	51.2	61.8	74.8	N	61.8		15/ 15	53.1	83.7	87.9	L

Table 4-16. Summary of Facility-wide Background Soil Concentrations Using 11 and 15 Samples (continued)

Inorganic Analytes and Detected Organic Analytes	*11 Background Samples*							*15 Background Samples*				
	Number of Results > Detection Limit	Average[a]	Maximum Detect	95% UTL[b]	Dist.[c]	Facility-Wide Background Criteria[d]		Number of Results > Detection Limit	Average[a]	Maximum Detect	UTL[b]	Dist.[c]
Organics (mg/kg)												
2-Methylnaphthalene	0/ 11		ND	ND	D	NA		2/ 15	0.211	0.3	0.3	D
Acenaphthene	0/ 11		ND	ND	D	NA		1/ 15	0.257	0.88	0.88	D
Acenaphthylene	0/ 11		ND	ND	D	NA		1/ 15	0.24	0.07	0.07	D
Anthracene	0/ 11		ND	ND	D	NA		2/ 15	0.26	1	1	D
Benz(a)anthracene	6/ 11	0.142	0.11	0.792	L	NA		10/ 15	0.449	4.1	4.1	X
Benzo(a)pyrene	4/ 11	0.167	0.1	0.1	X	NA		8/ 15	0.44	3.7	3.7	X
Benzo(b)fluoranthene	6/ 11	0.159	0.14	0.551	L	NA		10/ 15	0.536	4.8	4.8	X
Benzo(g,h,i)perylene	2/ 11	0.185	0.051	0.051	X	NA		6/ 15	0.258	1.3	1.3	X
Benzo(k)fluoranthene	2/ 11	0.186	0.054	0.054	X	NA		6/ 15	0.352	2.6	2.6	X
Bis(2-ethylhexyl) phthalate	1/ 11	0.198	0.047	0.047	D	NA		1/ 15	0.238	0.047	0.047	D
Carbazole	0/ 11		ND	ND	D	NA		2/ 15	0.234	0.66	0.66	D
Chrysene	6/ 11	0.147	0.12	0.12	X	NA		10/ 15	0.454	4	4	X
Dibenz(a,h)anthracene	0/ 11		ND	ND	D	NA		2/ 15	0.218	0.37	0.37	D
Dibenzofuran	0/ 11		ND	ND	D	NA		1/ 15	0.227	0.43	0.43	D
Fluoranthene	6/ 11	0.179	0.29	0.409	N	NA		10/ 15	0.919	9.5	9.5	X
Fluorene	0/ 11		ND	ND	D	NA		2/ 15	0.235	0.67	0.67	D
Indeno(1,2,3-cd)pyrene	1/ 11	0.198	0.054	0.054	D	NA		5/ 15	0.287	1.5	1.5	X
Phenanthrene	2/ 11	0.197	0.15	0.311	N	NA		6/ 15	0.607	5.8	5.8	X
Pyrene	6/ 11	0.169	0.23	0.23	X	NA		10/ 15	0.871	9.4	9.4	X

[a]Nondetects are included in the average at 1/2 the detection limit.

[b]The method of calculating the upper tolerance limit (UTL) depended on the probability distribution of the samples. For normal distributions, the untransformed data were used to calculate a 95% UTL. For lognormal distributions, log-transformed data were used to calculate a 95% UTL. For distributions that could not be determined, the maximum detect was used as a nonparametric UTL.

[c]Distribution Codes:

D = Too few detects (<50%) to determine distribution.
N = Normal.
L = Lognormal.
X = Neither normal nor lognormal.

[d]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of 95% UTL of the 95th percentile of the surface soil background concentrations or the maximum detect. Values in parentheses are detection limits for metals that were not detected in the background study. Organic and explosive compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.

NA = No background 95% UTL for comparison.
ND = Not detected.

Table 4-17. Facility-Wide Background with 11 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site E1/E2 for WBG Pad Pair 37/38 and Comparison of Metals to Facility-Wide Background Criteria

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Facility-Wide Background Criteria?
Inorganics (mg/kg)						
Aluminum	7/ 7	15200	11600	21400	17700	Yes
Arsenic	7/ 7	15.4	5.2	26.2	15.4	Yes
Barium	7/ 7	84	37.3	167	88.4	Yes
Beryllium	7/ 7	1.83	0.47	4.3	0.88	Yes
Cadmium	1/ 7	0.217	0.19	0.19	(0.6)	NA[c]
Calcium	7/ 7	36900	562	107000	15800	Yes
Chromium	7/ 7	12.9	10.5	15.1	17.4	No
Cobalt	7/ 7	5.87	3.7	8.4	10.4	No
Copper	7/ 7	13.2	7.1	21.6	17.7	Yes
Cyanide	2/ 7	0.632	1.4	1.5	(0.6)	NA
Iron	7/ 7	20400	11200	27900	23100	Yes
Lead	7/ 7	12.8	11.2	15	26.1	No
Magnesium	7/ 7	10400	2420	27000	3030	Yes
Manganese	7/ 7	664	197	1270	1450	No
Mercury	6/ 7	0.0424	0.014	0.062	0.036	Yes
Nickel	7/ 7	11.8	6.8	18.8	21.1	No
Potassium	7/ 7	1090	740	1730	927	Yes
Sodium	4/ 7	412	157	766	123	Yes
Thallium	7/ 7	0.113	0.054	0.17	(0.6)	NA[c]
Vanadium	7/ 7	18.4	14	21.3	31.1	No
Zinc	7/ 7	48.4	33	56.2	61.8	No
Semivolatile Organics (mg/kg)						
2-Methylnaphthalene	3/ 7	0.167	0.11	0.14	-	NA
4-Methylphenol	2/ 7	0.175	0.11	0.11	-	NA
Anthracene	1/ 7	0.192	0.14	0.14	-	NA
Benz(a)anthracene	4/ 7	0.937	0.15	5.2	-	NA
Benzo(a)pyrene	5/ 7	1.01	0.086	5.5	-	NA
Benzo(b)fluoranthene	5/ 7	1.71	0.12	10	-	NA
Benzo(g,h,i)perylene	5/ 7	0.753	0.074	3.9	-	NA
Benzo(k)fluoranthene	4/ 7	0.71	0.11	3.8	-	NA
Bis(2-ethylhexyl) phthalate	1/ 7	0.184	0.07	0.07	-	NA
Carbazole	1/ 7	0.196	0.17	0.17	-	NA
Chrysene	5/ 7	1.37	0.058	8.2	-	NA
Dibenz(a,h)anthracene	3/ 7	0.282	0.076	1	-	NA
Fluoranthene	4/ 7	1.67	0.22	10	-	NA
Indeno(1,2,3-cd) pyrene	4/ 7	0.707	0.14	3.6	-	NA
Naphthalene	3/ 7	0.163	0.11	0.12	-	NA
Phenanthrene	4/ 7	0.231	0.096	0.55	-	NA
Pyrene	4/ 7	0.969	0.21	5.2	-	NA

Table 4-17. Facility-Wide Background with 11 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site E1/E2 for WBG Pad Pair 37/38 and Comparison of Metals to Facility-Wide Background Criteria (continued)

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Facility-Wide Background Criteria?
Volatile Organics (mg/kg)						
Dimethylbenzene	7/ 7	0.00596	0.0025	0.013	-	NA
Ethylbenzene	4/ 7	0.00229	0.00082	0.003	-	NA
Methylene chloride	4/ 7	0.00429	0.0023	0.0091	-	NA
Tetrachloroethene	2/ 7	0.00284	0.0022	0.0024	-	NA
Toluene	4/ 7	0.00249	0.00096	0.0039	-	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of the 95% upper tolerance limit (UTL) of the 95th percentile or the maximum detect of the surface soil background concentrations. Values in parentheses are detection limits for metals that were not detected in the background study. Organic and explosive compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
NA = No background 95% UTL for comparison.
WBG = Winklepeck Burning Grounds.

Table 4-18. Facility-Wide Background with 15 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site E1/E2 for WBG Pad Pair 37/38 and Comparison of Metals to Background UTLs

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	15-Sample Background UTL[b]	Maximum Detect > 15-Sample Background UTL?
Inorganics (mg/kg)						
Aluminum	7/ 7	15200	11600	21400	24500	No
Arsenic	7/ 7	15.4	5.2	26.2	18.4	Yes
Barium	7/ 7	84	37.3	167	222	No
Beryllium	7/ 7	1.83	0.47	4.3	2.5	Yes
Cadmium	1/ 7	0.217	0.19	0.19	(0.6)	NA[c]
Calcium	7/ 7	36900	562	107000	620000	No
Chromium	7/ 7	12.9	10.5	15.1	21.9	No
Cobalt	7/ 7	5.87	3.7	8.4	15.6	No
Copper	7/ 7	13.2	7.1	21.6	21.3	Yes
Cyanide	2/ 7	0.632	1.4	1.5	2.4	No
Iron	7/ 7	20400	11200	27900	25700	Yes
Lead	7/ 7	12.8	11.2	15	66.5	No
Magnesium	7/ 7	10400	2420	27000	13200	Yes
Manganese	7/ 7	664	197	1270	4910	No
Mercury	6/ 7	0.0424	0.014	0.062	0.102	No
Nickel	7/ 7	11.8	6.8	18.8	25.7	No
Potassium	7/ 7	1090	740	1730	2390	No
Sodium	4/ 7	412	157	766	450	Yes
Thallium	7/ 7	0.113	0.054	0.17	(0.6)	NA[c]
Vanadium	7/ 7	18.4	14	21.3	45.9	No
Zinc	7/ 7	48.4	33	56.2	87.9	No
Semivolatile Organics (mg/kg)						
2-Methylnaphthalene	3/ 7	0.167	0.11	0.14	0.3	No
4-Methylphenol	2/ 7	0.175	0.11	0.11		NA
Anthracene	1/ 7	0.192	0.14	0.14	1.0	No
Benz(a)anthracene	4/ 7	0.937	0.15	5.2	4.1	Yes
Benzo(a)pyrene	5/ 7	1.01	0.086	5.5	3.7	Yes
Benzo(b)fluoranthene	5/ 7	1.71	0.12	10	4.8	Yes
Benzo(g,h,i)perylene	5/ 7	0.753	0.074	3.9	1.3	Yes
Benzo(k)fluoranthene	4/ 7	0.71	0.11	3.8	2.6	Yes
Bis(2-ethylhexyl) phthalate	1/ 7	0.184	0.07	0.07	0.047	Yes
Carbazole	1/ 7	0.196	0.17	0.17	0.66	No
Chrysene	5/ 7	1.37	0.058	8.2	4.0	Yes
Dibenz(a,h)anthracene	3/ 7	0.282	0.076	1	0.37	Yes
Fluoranthene	4/ 7	1.67	0.22	10	9.5	Yes
Indeno(1,2,3-cd) pyrene	4/ 7	0.707	0.14	3.6	1.5	Yes
Naphthalene	3/ 7	0.163	0.11	0.12	–	NA
Phenanthrene	4/ 7	0.231	0.096	0.55	5.8	No
Pyrene	4/ 7	0.969	0.21	5.2	9.4	No

Table 4-18. Facility-Wide Background with 15 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site E1/E2 for WBG Pad Pair 37/38 and Comparison of Metals to Background UTLs (continued)

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	15-Sample Background UTL[b]	Maximum Detect > 15-Sample Background UTL?
Volatile Organics (mg/kg)						
Dimethylbenzene	7/ 7	0.00596	0.0025	0.013	–	NA
Ethylbenzene	4/ 7	0.00229	0.00082	0.003	–	NA
Methylene chloride	4/ 7	0.00429	0.0023	0.0091	–	NA
Tetrachloroethene	2/ 7	0.00284	0.0022	0.0024	–	NA
Toluene	4/ 7	0.00249	0.00096	0.0039	–	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The 15-Sample Background UTL is the 95% upper tolerance limit of the 95th percentile of the 15 surface soil background concentrations or maximum detected values as a nonparametric UTL. Values in parentheses are detection limits for metals that were not detected in the background study.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
– = No UTL established, constituent not detected in background sample population.
NA = No background 95% UTL for comparison.
WBG = Winklepeck Burning Grounds.

Table 4-19. Facility-Wide Background with 11 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site E1/E2 for Metals

Analytes with Maximum Detect > Background Criteria	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Aluminum	N	10700		N	15200	T	Yes
Arsenic	N	10.5		N	15.4	T	No
Barium	N	65.2		N	84	T	No
Beryllium[c]	L	0.366		N	1.83	W	Yes
Calcium	L	4300		N	36900	W	No
Copper	X	11.5		N	13.2	W	No
Iron	N	17200		N	20400	T	No
Magnesium	N	1970		N	10400	T	Yes
Mercury	X	0.0447		N	0.0424	W	No
Potassium	N	621		N	1090	T	Yes
Sodium	X	42.8		N	412	W	Yes
Semivolatile Organics (mg/kg)							
2-Methylnaphthalene	ND			D	0.167		NA
4-Methylphenol	ND			D	0.175		NA
Anthracene	ND			D	0.192		NA
Benz(a)anthracene	L	0.142		X	0.937	W	No
Benzo(a)pyrene	X	0.167		L	1.01	W	Yes
Benzo(b)fluoranthene	L	0.159		L	1.71	W	Yes
Benzo(g,h,i)perylene	X	0.185		L	0.753	W	Yes
Benzo(k)fluoranthene	X	0.186		X	0.71	W	Yes
Bis(2-ethylhexyl)phthalate	D	0.198		D	0.184	W	No
Carbazole	ND			D	0.196		NA
Chrysene	X	0.147		L	1.37	W	No
Dibenz(a,h)anthracene	ND			D	0.282		NA
Fluoranthene	D	0.179		X	1.67	W	No
Indeno(1,2,3-cd)pyrene	D	0.198		X	0.707	W	Yes
Naphthalene	ND			D	0.163		NA
Phenanthrene	N	0.197		L	0.231	W	Yes
Pyrene	X	0.169		X	0.969	W	No
Volatile Organics (mg/kg)							
Dimethylbenzene	ND			L	0.00596		NA
Ethylbenzene	ND			X	0.00229		NA
Methylene chloride	ND			X	0.00429		NA
Tetrachloroethene	ND			D	0.00284		NA
Toluene	ND			L	0.00249		NA

[a]Background average includes 11 surface soil samples from Ravenna Army Ammunition Plant (RVAAP) facility-wide background study. Four samples that had been considered outliers for the background determination (BK0794, BK0795, BK0788, and BK0798) were removed for these comparisons.

[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site E1/E2. Nondetects are included in the average at 1/2 the detection limit.

Distribution Codes:
- D = Too few detects (<50%) to determine distribution.
- N = Normal.
- ND = Not detected.
- L = Lognormal.
- X = Neither normal nor lognormal.

Test Type Codes:
- T = t-test.
- W = Wilcoxon rank sum test.
- NA = No test was applicable because there were no background detects.

[c]Data for subsurface background were used for comparison.

Table 4-20. Facility-Wide Background with 15 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site E1/E2 for Metals

Analytes with Maximum Detect > Background UTL	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Arsenic	L	9.62		N	15.4	T	No
Beryllium[c]	X	0.63		N	1.83	W	Yes
Copper	X	12.7		N	13.2	W	No
Iron	N	16200		N	20400	T	No
Magnesium	X	3750		N	10400	T	Yes
Sodium	X	125		N	412	W	No
Semivolatile Organics (mg/kg)							
4-Methylphenol	ND			D	0.175		NA
Benz(a)anthracene	X	0.449		X	0.937	W	No
Benzo(a)pyrene	X	0.44		L	1.01	W	No
Benzo(b)fluoranthene	X	0.536		L	1.71	W	No
Benzo(g,h,i)perylene	X	0.258		L	0.753	W	No
Benzo(k)fluoranthene	X	0.352		X	0.71	W	No
Bis(2-ethylhexyl)phthalate	D	0.238		D	0.184	W	No
Chrysene	X	0.454		L	1.37	W	No
Dibenz(a,h)anthracene	D	0.218		D	0.282	W	No
Fluoranthene	X	0.919		X	1.67	W	No
Indeno(1,2,3-cd)pyrene	X	0.287		X	0.707	W	No
Naphthalene	ND			D	0.163		NA
Volatile Organics (mg/kg)							
Dimethylbenzene	ND			L	0.00596		NA
Ethylbenzene	ND			X	0.00229		NA
Methylene chloride	ND			X	0.00429		NA
Tetrachloroethene	ND			D	0.00284		NA
Toluene	ND			L	0.00249		NA

[a]Background average includes 15 surface soil samples from the Ravenna Army Ammunition Plant (RVAAP) facility-wide background study.
[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site E1/E2. Nondetects are included in the average at 1/2 the detection limit.
Distribution Codes:
D = Too few detects (<50%) to determine distribution.
N = Normal.
ND = Not detected.
L = Lognormal.
X = Neither normal nor lognormal.
Test Type Codes:
T = t-test.
W = Wilcoxon rank sum test.
NA = No test was applicable because there were no background detects.
[c]Data for subsurface background were used for comparison.

Table 4-21. Comparison of Maximum and Average Concentrations with a Range of Ecological Screening Values for Soil Samples at Reference Site E1/E2

Analytes with Reference Averages Greater than 15-Sample Background Averages	Soil Statistics		Range of Ecological Screening Values (ESV)		Reference > Upper Limit of ESV Range?	
	Maximum Detect	Average[a]	Lower[b]	Upper[b]	Max.	Average
Inorganics (mg/kg)						
Beryllium	4.3	1.83	1.1	10	No	No
Magnesium	27000	10400	NA	NA	NA	NA
Semivolatile Organics (mg/kg)						
4-Methylphenol	0.11	0.175	NA	NA	NA	NA
Naphthalene	0.12	0.163	0.1	40	No	No
Volatile Organics (mg/kg)						
Dimethylbenzene	0.013	0.00596	0.05	10	No	No
Ethylbenzene	0.003	0.00229	0.05	50	No	No
Methylene chloride	0.0091	0.00429	2	4	No	No
Tetrachloroethene	0.0024	0.00284	0.001	60	No	No
Toluene	0.0039	0.00249	.05	200	No	No

[a] Nondetects are included in the average at 1/2 the detection limit.
[b]The receptors and sources for each ESV may be found in Table 4-32.
NA = ESV not available.

Table 4-22. Facility-Wide Background with 11 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site S1/S2 for WBG Pad Pair 58/59 and Comparison of Metals to Background Criteria

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Facility-Wide Background Criteria?
Inorganics (mg/kg)						
Aluminum	7/ 7	13100	10000	16200	17700	No
Arsenic	7/ 7	11	5.7	15	15.4	No
Barium	7/ 7	71.9	47.5	114	88.4	Yes
Beryllium	7/ 7	0.606	0.41	0.86	0.88	No
Calcium	7/ 7	1090	473	1570	15800	No
Chromium	7/ 7	17.3	13.5	20	17.4	Yes
Cobalt	7/ 7	13.1	5.6	36.4	10.4	Yes
Copper	7/ 7	15.9	10.2	22.3	17.7	Yes
Iron	7/ 7	26300	20800	30400	23100	Yes
Lead	7/ 7	15.2	11.2	19.5	26.1	No
Magnesium	7/ 7	3030	2270	4610	3030	Yes
Manganese	7/ 7	360	112	644	1450	No
Mercury	7/ 7	0.0226	0.012	0.033	0.036	No
Nickel	7/ 7	20.8	13.7	36.9	21.1	Yes
Potassium	7/ 7	1200	981	1450	927	Yes
Thallium	7/ 7	0.147	0.13	0.18	(0.6)	NA[c]
Vanadium	7/ 7	21.8	17.4	24.5	31.1	No
Zinc	7/ 7	59.5	44.3	68.8	61.8	Yes
Semivolatile Organics (mg/kg)						
Benzoic acid	1/ 7	0.91	0.23	0.23	-	NA
Bis(2-ethylhexyl) phthalate	1/ 7	0.19	0.09	0.09	-	NA
Volatile Organics (mg/kg)						
Dimethylbenzene	1/ 7	0.00314	0.0027	0.0027	-	NA
Methylene chloride	1/ 7	0.003	0.0018	0.0018	-	NA
Toluene	4/ 7	0.00226	0.00081	0.002	-	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of the 95% upper tolerance limit (UTL) of the 95th percentile or the maximum detect of the surface soil background concentrations. Values in parentheses are detection limits for metals that were not detected in the background study. Organic compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
NA = No background 95% UTL for comparison.

Table 4-23. Facility-Wide Background with 15 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site S1/S2 for WBG Pad Pair 58/59 and Comparison of Metals to Background UTL

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	15-Sample Background UTL[b]	Maximum Detect > 15-Sample Background UTL?
Inorganics (mg/kg)						
Aluminum	7/ 7	13100	10000	16200	24500	No
Arsenic	7/ 7	11	5.7	15	18.4	No
Barium	7/ 7	71.9	47.5	114	222	No
Beryllium	7/ 7	0.606	0.41	0.86	2.5	No
Calcium	7/ 7	1090	473	1570	620000	No
Chromium	7/ 7	17.3	13.5	20	21.9	No
Cobalt	7/ 7	13.1	5.6	36.4	15.6	Yes
Copper	7/ 7	15.9	10.2	22.3	21.3	Yes
Iron	7/ 7	26300	20800	30400	25700	Yes
Lead	7/ 7	15.2	11.2	19.5	66.5	No
Magnesium	7/ 7	3030	2270	4610	13200	No
Manganese	7/ 7	360	112	644	4910	No
Mercury	7/ 7	0.0226	0.012	0.033	0.102	No
Nickel	7/ 7	20.8	13.7	36.9	25.7	Yes
Potassium	7/ 7	1200	981	1450	2390	No
Thallium	7/ 7	0.147	0.13	0.18	(0.64)	NA[c]
Vanadium	7/ 7	21.8	17.4	24.5	45.9	No
Zinc	7/ 7	59.5	44.3	68.8	87.9	No
Semivolatile Organics (mg/kg)						
Benzoic acid	1/ 7	0.91	0.23	0.23		NA
Bis(2-ethylhexyl) phthalate	1/ 7	0.19	0.09	0.09	0.047	Yes
Volatile Organics (mg/kg)						
Dimethylbenzene	1/ 7	0.00314	0.0027	0.0027	–	NA
Methylene chloride	1/ 7	0.003	0.0018	0.0018	–	NA
Toluene	4/ 7	0.00226	0.00081	0.002	–	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The 15-Sample Background UTL is the 95% upper tolerance limit of the 95th percentile of the 15 surface soil background concentrations or maximum detected value as a non-parametric UTL. Values in parentheses are detection limits for metals that were not detected in the background study.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
– = No UTL established, constituent not detected in the background sample population.
NA = No background 95% UTL for comparison.

Table 4-24. Facility-Wide Background with 11 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site S1/S2 for Metals

Analytes with Maximum Detect > Background Criteria	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Barium	N	65.2		N	71.9	T	No
Chromium	N	12.1		N	17.3	T	Yes
Cobalt	N	7.53		L	13.1	W	No
Copper	X	11.5		N	15.9	W	Yes
Iron	N	17200		N	26300	T	Yes
Magnesium	N	1970		N	3030	T	Yes
Nickel	N	13.6		N	20.8	T	Yes
Potassium	N	621		N	1200	T	Yes
Zinc	N	51.2		N	59.5	T	Yes
Semivolatile Organics (mg/kg)							
Benzoic acid	NA			D	0.91		NA
Bis(2-ethylhexyl)phthalate	D	0.198		D	0.19	W	No
Volatile Organics (mg/kg)							
Dimethylbenzene	ND				0.00314		NA
Methylene chloride	ND				0.003		NA
Toluene	ND				0.00226		NA

[a]Background average includes 11 surface soil samples from the Ravenna Army Ammunition Plant (RVAAP) facility-wide background study. Four samples that had been considered outliers for the background determination (BK0794, BK0795, BK0788, and BK0798) were removed for these comparisons.

[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site S1/S2. Nondetects are included in the average at 1/2 the detection limit.

Distribution Codes:

D = Too few detects (<50%) to determine distribution.
N = Normal.
NA = Not analyzed for.
ND = Not detected.
L = Lognormal.
X = Neither normal nor lognormal.

Test Type Codes:

T = t-test.
W = Wilcoxon rank sum test.
NA = No test was applicable because there were no background detects.

Table 4-25. Facility-Wide Background with 15 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site S1/S2 for Metals

Analytes with Maximum Detect > 15 sample Background UTL	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Cobalt	L	6.87		L	13.1	W	Yes
Copper	X	12.7		N	15.9	W	No
Iron	N	16200		N	26300	T	Yes
Nickel	N	13.8		N	20.8	T	Yes
Semivolatile Organics (mg/kg)							
Benzoic acid	NA			D	0.91		NA
Bis(2-ethylhexyl)phthalate	D	0.238		D	0.19	W	No
Volatile Organics (mg/kg)							
Dimethylbenzene	ND				0.00314		NA
Methylene chloride	ND				0.003		NA
Toluene	ND				0.00226		NA

[a]Background average includes 15 surface soil samples from the Ravenna Army Ammunition Plant (RVAAP) facility-wide background study.
[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site S1/S2.
Nondetects are included in the average at 1/2 the detection limit.
Distribution Codes:
D = Too few detects (<50%) to determine distribution.
N = Normal.
NA = Not analyzed for.
ND = Not detected.
L = Lognormal.
X = Neither normal nor lognormal.
Test Type Codes:
T = t-test.
W = Wilcoxon rank sum test.

Table 4-26. Comparison of Maximum and Average Concentrations with a Range of Ecological Screening Values for Soil Samples at Reference Site S1/S2

Analytes with Reference Averages Greater than 15-Sample Background Averages	Soil Statistics		Range of Ecological Screening Values (ESVs)			Reference > Upper Limit of ESV Range?	
	Maximum Detect	Average[a]	Lower[b]	Upper[b]		Max.	Average
Inorganics (mg/kg)							
Cobalt	36.4	13.1	0.14	1000		No	No
Iron	30400	26300	200	200		Yes	Yes
Nickel	36.9	20.8	13.6	90		No	No
Semivolatile Organics (mg/kg)							
Benzoic acid	0.23	0.91	NA	NA		NA	NA
Volatile Organics (mg/kg)							
Dimethylbenzene	0.0027	0.00314	0.05	10		No	No
Methylene chloride	0.0018	0.003	2	4		No	No
Toluene	0.002	0.00226	0.05	200		No	No

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The receptors and sources for each ESV may be found in Table 4-32.
NA = ESV not available.

Table 4-27. Facility-Wide Background with 11 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site J1/J2 for WBG Pad Pair 66/67 and Comparison of Metals to Background Criteria

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background Criteria[b]	Maximum Detect > Site Background Criteria?
Inorganics (mg/kg)						
Aluminum	7/ 7	16300	12300	20200	17700	Yes
Arsenic	7/ 7	13.2	11.8	14.6	15.4	No
Barium	7/ 7	63.9	35.4	82.2	88.4	No
Beryllium	7/ 7	0.714	0.67	0.78	0.88	No
Calcium	7/ 7	1270	943	2090	15800	No
Chromium	7/ 7	21.8	19.7	26.4	17.4	Yes
Cobalt	7/ 7	12.6	10.1	15.7	10.4	Yes
Copper	7/ 7	21.9	18.9	25.9	17.7	Yes
Iron	7/ 7	31100	27400	35800	23100	Yes
Lead	7/ 7	16.5	13	20.8	26.1	No
Magnesium	7/ 7	4100	3680	4870	3030	Yes
Manganese	7/ 7	280	172	355	1450	No
Mercury	7/ 7	0.026	0.021	0.042	0.036	Yes
Nickel	7/ 7	26.3	23.8	29.2	21.1	Yes
Potassium	7/ 7	1680	1220	2140	927	Yes
Thallium	7/ 7	0.157	0.13	0.17	(0.6)	NA[c]
Vanadium	7/ 7	26.7	23.5	31.7	31.1	Yes
Zinc	7/ 7	62.5	56.4	82.7	61.8	Yes
Semivolatile Organics (mg/kg)						
Benzoic acid	1/ 7	0.899	0.19	0.19	-	NA
Bis(2-ethylhexyl)phthalate	2/ 7	0.178	0.071	0.13	-	NA
Fluoranthene	2/ 7	0.17	0.074	0.085	-	NA
Pyrene	1/ 7	0.188	0.069	0.069	-	NA
Volatile Organics (mg/kg)						
Dimethylbenzene	4/ 7	0.00364	0.0027	0.0065	-	NA
Ethylbenzene	2/ 7	0.00257	0.00076	0.0011	-	NA
Toluene	1/ 7	0.00288	0.00098	0.00098	-	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The Ravenna Army Ammunition Plant (RVAAP) facility-wide background criteria is the smaller of the 95% upper tolerance limit (UTL) of the 95th percentile or the maximum detect of the surface soil background concentrations. Values in parentheses are detection limits for metals that were not detected in the background study. Organic compounds were assumed to be from human activities and, therefore, were not used to develop background screening criteria.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
NA = No background 95% UTL for comparison.

Table 4-28. Facility-Wide Background with 15 Samples: Summary of Analytes Detected in Soil Samples Taken in May 2002 at Reference Site J1/J2 for WBG Pad Pair 66/67 and Comparison of Metals to Background UTL

Analyte Detected	Number of Results > Detection Limit	Average[a]	Minimum Detect	Maximum Detect	Facility-Wide Surface Soil Background UTL[b]	Maximum Detect > Site Background UTL?
Inorganics (mg/kg)						
Aluminum	7/ 7	16300	12300	20200	24500	No
Arsenic	7/ 7	13.2	11.8	14.6	18.4	No
Barium	7/ 7	63.9	35.4	82.2	222	No
Beryllium	7/ 7	0.714	0.67	0.78	2.5	No
Calcium	7/ 7	1270	943	2090	620000	No
Chromium	7/ 7	21.8	19.7	26.4	21.9	Yes
Cobalt	7/ 7	12.6	10.1	15.7	15.6	Yes
Copper	7/ 7	21.9	18.9	25.9	21.3	Yes
Iron	7/ 7	31100	27400	35800	25700	Yes
Lead	7/ 7	16.5	13	20.8	66.5	No
Magnesium	7/ 7	4100	3680	4870	13200	No
Manganese	7/ 7	280	172	355	4910	No
Mercury	7/ 7	0.026	0.021	0.042	0.102	No
Nickel	7/ 7	26.3	23.8	29.2	25.7	Yes
Potassium	7/ 7	1680	1220	2140	2390	No
Thallium	7/ 7	0.157	0.13	0.17	(6.4)	NA[c]
Vanadium	7/ 7	26.7	23.5	31.7	45.9	No
Zinc	7/ 7	62.5	56.4	82.7	87.9	No
Semivolatile Organics (mg/kg)						
Benzoic acid	1/ 7	0.899	0.19	0.19	-	NA
Bis(2-ethylhexyl)phthalate	2/ 7	0.178	0.071	0.13	0.047	Yes
Fluoranthene	2/ 7	0.17	0.074	0.085	9.5	No
Pyrene	1/ 7	0.188	0.069	0.069	9.4	No
Volatile Organics (mg/kg)						
Dimethylbenzene	4/ 7	0.00364	0.0027	0.0065	-	NA
Ethylbenzene	2/ 7	0.00257	0.00076	0.0011	-	NA
Toluene	1/ 7	0.00288	0.00098	0.00098	-	NA

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The 15-Sample Background UTL is the 95% upper tolerance limit of the 95th percentile of the 15 surface soil background concentrations or maximum detected value as the nonparametric UTL. Values in parentheses are detection limits for metals that were not detected in the background study.
[c]Analyte not considered in further background screening because the maximum detect at the reference site was less than the detection limit from the facility-wide background study.
– = No UTL established, constituent not detected in the background sample population.
NA = No background 95% UTL for comparison.

Table 4-29. Facility-Wide Background with 11 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site J1/J2 for Metals

Analytes with Maximum Detect > Background Criteria	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Aluminum	N	10700		N	16300	T	Yes
Chromium	N	12.1		N	21.8	T	Yes
Cobalt	N	7.53		N	12.6	T	Yes
Copper	X	11.5		N	21.9	W	Yes
Iron	N	17200		N	31100	T	Yes
Magnesium	N	1970		N	4100	T	Yes
Mercury	X	0.0447		X	0.026	W	No
Nickel	N	13.6		N	26.3	T	Yes
Potassium	N	621		N	1680	T	Yes
Vanadium	N	19		N	26.7	T	Yes
Zinc	N	51.2		X	62.5	W	Yes
Semivolatile Organics (mg/kg)							
Benzoic acid	NA			D	0.899		NA
Bis(2-ethylhexyl)phthalate	D	0.198		D	0.178	W	No
Fluoranthene	N	0.1790		D	0.17	W	No
Pyrene	X	0.169		D	0.188	W	No
Volatile Organics (mg/kg)							
Dimethylbenzene	ND			X	0.00364		NA
Ethylbenzene	ND			D	0.00257		NA
Toluene	ND			D	0.00288		NA

[a]Background average includes 11 surface soil samples from the Ravenna Army Ammunition Plant (RVAAP) facility-wide background study. Four samples that had been considered outliers for the background determination (BK0794, BK0795, BK0788, and BK0798) were removed for these comparisons.

[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site J1/J2. Nondetects are included in the average at 1/2 the detection limit.

Distribution Codes:

D = Too few detects (<50%) to determine distribution.
N = Normal.
NA = Not analyzed for.
ND = Not detected.
L = Lognormal.
X = Neither normal nor lognormal.

Test Type Codes:

T = t-test.
W = Wilcoxon rank sum test.

Table 4-30. Facility-Wide Background with 15 Samples: Comparison of Average Concentrations Between Background and Soil Samples at Reference Site J1/J2 for Metals

Analytes with Maximum Detect > Background Criteria	Background[a]			Reference[b]		Test Type	Reference Average > Background Average?
	Distribution	Average (mg/kg)		Distribution	Average (mg/kg)		
Inorganics (mg/kg)							
Chromium	N	12		N	21.8	T	Yes
Cobalt	L	6.87		N	12.6	W	Yes
Copper	X	12.7		N	21.9	W	No
Iron	N	16200		N	31100	T	Yes
Nickel	N	13.8		N	26.3	T	Yes
Semivolatile Organics (mg/kg)							
Benzoic acid	NA			D	0.899		NA
Bis(2-ethylhexyl)phthalate	D	0.238		D	0.178	W	No
Volatile Organics (mg/kg)							
Dimethylbenzene	ND			X	0.00364		NA
Ethylbenzene	ND			D	0.00257		NA
Toluene	ND			D	0.00288		NA

[a]Background average includes 15 surface soil samples from the Ravenna Army Ammunition Plant (RVAAP) facility-wide background study

[b]Reference average includes 7 surface soil samples from the Biological Field-truthing Study reference site J1/J2. Nondetects are included in the average at 1/2 the detection limit.

Distribution Codes:

D = Too few detects (<50%) to determine distribution.
N = Normal.
NA = Not analyzed for.
ND = Not detected.
L = Lognormal.
X = Neither normal nor lognormal.

Test Type Codes:

T = t-test.
W = Wilcoxon rank sum test.

Table 4-31. Comparison of Maximum and Average Concentrations with a Range of Ecological Screening Values for Soil Samples at Reference Site J1/J2

Analytes with Reference Averages Greater than 15-Sample Background Averages	Soil Statistics		Range of Ecological Screening Values (ESVs)			Reference > Upper Limit of ESV Range?	
	Maximum Detect	Average[a]	Lower[b]	Upper[b]		Max.	Average
Inorganics (mg/kg)							
Chromium	26.4	21.8	0.4	100		No	No
Cobalt	15.7	12.6	0.14	1000		No	No
Iron	35800	31100	200	200		Yes	Yes
Nickel	29.2	26.3	13.6	90		No	No
Semivolatile Organics (mg/kg)							
Benzoic acid	0.19	0.899	NA	NA		NA	NA
Volatile Organics (mg/kg)							
Dimethylbenzene	0.0065	0.00364	0.05	10		No	No
Ethylbenzene	0.0011	0.00257	0.05	50		No	No
Toluene	0.00098	0.00288	0.05	200		No	No

[a]Nondetects are included in the average at 1/2 the detection limit.
[b]The receptors and sources for each ESV may be found in Table 4-32.
NA = ESV not available.

Table 4-32. Ecological Screening Values for Comparison to Reference Soil Data

Analyte	Ecological Screening Value for Soil					
	Lower			Higher		
	Value	Receptor	Source	Value	Receptor	Source
Inorganics (mg/kg)						
Aluminum	50	Plants	Efroymson et al. 1997b in WSRC 1999	600	Soil microbial activity	Efroymson et al. 1997a
Beryllium	1.1	Not specified in WSRC 1999	Crommentuijn et al. 1977 in WSRC 1999	10	Plants	Efroymson et al. 1997b
Chromium	0.4	Soil invertebrates	Efroymson et al. 1997a in WSRC 1999	100	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total optimum level)
Cobalt	0.14	Unspecified ecological receptors	EPA Region 5 EDQLs	1000	Soil microbial activity	Efroymson et al. 1997a
Copper	0.3	Unspecified ecological receptors	EPA Region 5 EDQLs	100	Plants	Efroymson et al. 1997b
Cyanide	1.3	Unspecified ecological receptors	EPA Region 5 EDQLs	5	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999
Iron	200	Soil microbial activity	Efroymson et al. 1997a in WSRC 1999	200	Soil microbial activity	Efroymson et al. 1997a
Magnesium	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Mercury	0.1	Soil invertebrates	Efroymson et al. 1997a in WSRC 1999	30	Soil microbial activity	Efroymson et al. 1997a
Nickel	13.6	Unspecified ecological receptors	EPA Region 5 EDQLs	90	Soil microbial activity	Efroymson et al. 1997a
Potassium	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Sodium	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Vanadium	1.6	Unspecified ecological receptors	EPA Region 5 EDQLs	20	Soil microbial activity	Efroymson et al. 1997a
Zinc	6.6	Unspecified ecological receptors	EPA Region 5 EDQLs	720	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (action level)
Semivolatile Organics (mg/kg)						
2-Methylnaphthalene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)

Table 4-32. Ecological Screening Values for Comparison to Reference Soil Data (continued)

Analyte	Ecological Screening Value for Soil					
	Lower			Higher		
	Value	Receptor	Source	Value	Receptor	Source
4-Methylphenol	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Anthracene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	1480	Unspecified ecological receptors	EPA Region 5 EDQLs
Benz(a)anthracene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Benzo(a)pyrene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Benzo(b)fluoranthene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	59.8	Unspecified ecological receptors	EPA Region 5 EDQLs
Benzo(g,h,i)perylene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	119	Unspecified ecological receptors	EPA Region 5 EDQLs
Benzo(k)fluoranthene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Benzoic acid	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Bis(2-ethylhexyl)phthalate	0.1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing in WSRC 1999 (total phthalates)	0.1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing in WSRC 1999 (total phthalates)
Carbazole	None	Not applicable	Not applicable	None	Not applicable	Not applicable
Chrysene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Dibenz(a,h)anthracene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Fluoranthene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	122	Unspecified ecological receptors	EPA Region 5 EDQLs
Indeno(1,2,3-cd)pyrene	1	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH optimum level)	109	Unspecified ecological receptors	EPA Region 5 EDQLs

Table 4-32. Ecological Screening Values for Comparison to Reference Soil Data (continued)

Analyte	Ecological Screening Value for Soil					
	Lower			Higher		
	Value	Receptor	Source	Value	Receptor	Source
Naphthalene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	40	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (total PAH action level)
Phenanthrene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	45.7	Unspecified ecological receptors	EPA Region 5 EDQLs
Pyrene	0.1	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	78.5	Unspecified ecological receptors	EPA Region 5 EDQLs
Volatile Organics (mg/kg)						
Dimethylbenzene	0.05	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	10	Unspecified ecological receptors	EPA Region 5 EDQLs
Ethylbenzene	0.05	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	50	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing (action level)
Methylene chloride	2	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing in WSRC 1999	4	Unspecified ecological receptors	EPA Region 5 EDQLs
Tetrachloroethene	0.001	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing in WSRC 1999 (optimum level)	60	Human residential or industrial use or biota (Ministry of Housing)	Ministry of Housing in WSRC 1999 (action level)
Toluene	0.05	Not specified in WSRC 1999	Beyer 1990 in WSRC 1999	200	Plants	Efroymson et al. 1997b

Efroymson, R. A., Will, M. E., and Suter II, G. W. 1997a. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.* ES/ER/TM-126/R2. Prepared by Lockheed Martin Energy Systems for the U.S. Department of Energy, Oak Ridge, Tennessee.

Efroymson, R. A., Will, M. E., Suter II, G. W., and Wooten, A. C. 1997b. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.* ES/ER/TM-85/R3. Prepared by Lockheed Martin Energy Systems for the U.S. Department of Energy, Oak Ridge, Tennessee.

EPA Region 5 EDQLs (Ecological Data Quality Levels) [no date given]. U.S. Environmental Protection Agency, Region 5, Chicago, Illinois. URL http://www.epa.gov/reg5rcra/ca/edql10-4-99.PDF

Ministry of Housing (no date given). *Dutch soil cleanup values.* URL http://www.contaminatedland.co.uk/std-guid/dutch-l.htm

WSRC. 1999. *Ecological Screening Values (ESVs). April 1999*. WSRC-TR-98-01100. Westinghouse Savannah River Company, Savannah River Site, Aiken, South Carolina.

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ATTACHMENT 1
TO SECTION 4.0 STUDY SITES AND SOILS
EXCEL FILES FOR REFERENCE SOIL CHEMICALS

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Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			Soil	Soil	Soil	Soil
Site			E1/E2	E1/E2	E1/E2	E1/E2
Plot			Plot 146	Plot 154	Plot 223	Plot 007
Sample ID			REF3031	REF3032	REF3033	REF3034
Date			05/10/2002	05/10/2002	05/10/2002	05/10/2002
Depth (ft)			0 - 1	0 - 1	0 - 1	0 - 1
Field Type			Grab	Grab	Grab	Grab
Analyte	Units	RVAAP Site-Wide Background Criteria				
Cyanide	MG/KG		<0.62 U	1.5 =*	<0.59 U	<0.61 U
Aluminum	MG/KG	17700	13000 =	21400 =*	12800 =	11900 =
Antimony	MG/KG	0.96	<1.2 U	<1.3 U	<1.2 U	<1.2 UJ
Arsenic	MG/KG	15.4	19.5 =*	5.2 =	20.6 =*	17.9 =*
Barium	MG/KG	88.4	37.3 =	167 =*	38 =	37.5 =
Beryllium	MG/KG	0.88	0.54 J	4.3 =*	0.51 J	0.47 J
Cadmium	MG/KG		<0.62 U	<0.17 U	<0.59 U	<0.61 U
Calcium	MG/KG	15800	2160 =	107000 =*	606 =	562 J
Chromium	MG/KG	17.4	14.9 =	10.5 =	15.1 =	14.5 =
Cobalt	MG/KG	10.4	8.4 =	4.4 =	7.7 =	7.2 =
Copper	MG/KG	17.7	21.6 =*	7.1 =	19.9 =*	17.8 J*
Iron	MG/KG	23100	27200 =*	11200 =	27900 =*	25900 =*
Lead	MG/KG	26.1	13.9 =	11.5 =	13.3 =	13.2 =
Magnesium	MG/KG	3030	3110 =*	27000 =*	2420 =	2520 =
Manganese	MG/KG	1450	236 =	1230 =	197 =	322 J
Mercury	MG/KG	0.036	0.019 J	0.052 J*	0.056 J*	0.014 J
Nickel	MG/KG	21.1	18.8 =	6.8 =	17.5 =	15.1 =
Potassium	MG/KG	927	859 =	1730 =*	804 =	898 =
Selenium	MG/KG	1.4	<2.5 U	<1.5 U	<2.3 U	<2.4 U
Silver	MG/KG		<0.62 U	<0.64 U	<0.59 U	<0.61 U
Sodium	MG/KG	123	<617 U	766 =*	<586 U	<608 U
Thallium	MG/KG		0.13 J*	0.054 J*	0.14 J*	0.12 =*
Vanadium	MG/KG	31.1	19.7 =	14 =	21 =	21.3 =
Zinc	MG/KG	61.8	55.8 =	56.2 =	51.4 =	47.4 =

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			Soil	Soil	Soil	Soil
Site			E1/E2	E1/E2	E1/E2	J1/J2
Plot			Plot 142	Plot 156	Plot 173	Plot 035
Sample ID			REF3035	REF3036	REF3037	REF3038
Date			05/10/2002	05/10/2002	05/10/2002	05/10/2002
Depth (ft)			0 - 1	0 - 1	0 - 1	0 - 1
Field Type			Grab	Grab	Grab	Grab
Analyte	Units	RVAAP Site-Wide Background Criteria				
Cyanide	MG/KG		<0.61 U	1.4 =*	<0.62 U	<0.63 U
Aluminum	MG/KG	17700	18800 =*	11600 =	16900 =	12300 =
Antimony	MG/KG	0.96	<1.2 U	<1.2 U	<1.2 U	<1.3 UJ
Arsenic	MG/KG	15.4	10.8 =	26.2 =*	7.3 =	14.6 =
Barium	MG/KG	88.4	135 =*	56.2 =	117 =*	35.4 =
Beryllium	MG/KG	0.88	3.3 =*	1.1 =*	2.6 =*	0.67 =
Cadmium	MG/KG		<0.055 U	<0.61 U	0.19 J*	<0.63 U
Calcium	MG/KG	15800	71300 =*	19500 =*	56900 =*	1050 =
Chromium	MG/KG	17.4	11.5 =	10.6 =	13.1 =	20.3 =*
Cobalt	MG/KG	10.4	5.2 =	3.7 =	4.5 =	13.9 =*
Copper	MG/KG	17.7	7.7 =	10.2 =	8 =	25.9 J*
Iron	MG/KG	23100	16800 =	20100 =	13800 =	35800 =*
Lead	MG/KG	26.1	11.5 =	11.2 =	15 =	20.8 =
Magnesium	MG/KG	3030	18400 =*	5630 =*	14000 =*	3680 =*
Manganese	MG/KG	1450	1270 =	345 =	1050 =	355 J
Mercury	MG/KG	0.036	0.034 J	<0.12 U	0.062 J*	0.021 J
Nickel	MG/KG	21.1	8 =	7.9 =	8.2 =	23.8 =*
Potassium	MG/KG	927	1420 =*	740 =	1190 =*	1220 =*
Selenium	MG/KG	1.4	<0.46 U	<2.4 U	<0.64 U	<2.5 U
Silver	MG/KG		<0.61 U	<0.61 U	<0.62 U	<0.63 U
Sodium	MG/KG	123	608 =*	157 J*	447 J*	<629 U
Thallium	MG/KG		0.17 J*	0.069 J*	0.11 J*	0.13 =*
Vanadium	MG/KG	31.1	17.6 =	18.6 =	16.3 =	24.8 =
Zinc	MG/KG	61.8	47.1 =	33 =	48 =	60.3 =

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			Soil	Soil	Soil	Soil
Site			J1/J2	J1/J2	J1/J2	J1/J2
Plot			Plot 037	Plot 108	Plot 109	Plot 046
Sample ID			REF3039	REF3040	REF3041	REF3042
Date			05/10/2002	05/10/2002	05/10/2002	05/10/2002
Depth (ft)			0 - 1	0 - 1	0 - 1	0 - 1
Field Type			Grab	Grab	Grab	Grab
Analyte	Units	RVAAP Site-Wide Background Criteria				
Cyanide	MG/KG		<0.67 U	<0.62 U	<0.63 U	<0.66 U
Aluminum	MG/KG	17700	20200 =*	17400 =	18200 =*	14100 =
Antimony	MG/KG	0.96	<1.3 UJ	<1.2 UJ	<1.3 UJ	<1.3 UJ
Arsenic	MG/KG	15.4	13.5 =	11.8 =	12.7 =	12.6 =
Barium	MG/KG	88.4	65.4 =	63.3 =	57.8 =	82.2 =
Beryllium	MG/KG	0.88	0.78 =	0.67 =	0.71 =	0.69 =
Cadmium	MG/KG		<0.67 U	<0.62 U	<0.63 U	<0.66 U
Calcium	MG/KG	15800	943 =	1100 =	976 =	2090 =
Chromium	MG/KG	17.4	26.4 =*	21.5 =*	23.4 =*	19.7 =*
Cobalt	MG/KG	10.4	11.6 =*	10.1 =	10.4 =	11.4 =*
Copper	MG/KG	17.7	23.6 J*	20.7 J*	23.4 J*	20.1 J*
Iron	MG/KG	23100	34500 =*	28400 =*	31700 =*	27400 =*
Lead	MG/KG	26.1	20.2 =	13 =	15.2 =	15.2 =
Magnesium	MG/KG	3030	4870 =*	3860 =*	4230 =*	4510 =*
Manganese	MG/KG	1450	266 J	172 J	236 J	293 J
Mercury	MG/KG	0.036	0.042 J*	0.023 J	0.024 J	0.021 J
Nickel	MG/KG	21.1	29.2 =*	24.3 =*	27.3 =*	27.9 =*
Potassium	MG/KG	927	2140 =*	1900 =*	1990 =*	1740 =*
Selenium	MG/KG	1.4	<2.7 U	<2.5 U	<2.5 U	<2.6 U
Silver	MG/KG		<0.67 U	<0.62 U	<0.63 U	<0.66 U
Sodium	MG/KG	123	<672 U	<620 U	<628 U	<661 U
Thallium	MG/KG		0.16 =*	0.16 =*	0.17 =*	0.16 =*
Vanadium	MG/KG	31.1	31.7 =*	27 =	27.9 =	23.5 =
Zinc	MG/KG	61.8	82.7 =*	60.2 =	61.8 =	57.2 =

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			Soil	Soil	Soil	Soil
Site			J1/J2	J1/J2	J1/J2	S1/S2
Plot			Plot 212	Plot 249	Plot 249	Plot 088
Sample ID			REF3043	REF3044	REF3058	REF3045
Date			05/10/2002	05/10/2002	05/10/2002	05/09/2002
Depth (ft)			0 - 1	0 - 1	0 - 1	0 - 1
Field Type			Grab	Grab	Field Duplicate	Grab
Analyte	Units	RVAAP Site-Wide Background Criteria				
Cyanide	MG/KG		<0.63 U	<0.64 U	<0.63 U	<0.63 U
Aluminum	MG/KG	17700	16000 =	15700 =	15300 =	13900 =
Antimony	MG/KG	0.96	<1.3 UJ	<1.3 UJ	<1.3 UJ	<1.3 UJ
Arsenic	MG/KG	15.4	13.9 =	13.3 =	14 =	15 =
Barium	MG/KG	88.4	70.5 =	72.4 =	53.2 =	65.6 =
Beryllium	MG/KG	0.88	0.75 =	0.73 =	0.62 J	0.57 J
Cadmium	MG/KG		<0.63 U	<0.64 U	<0.63 U	<0.63 U
Calcium	MG/KG	15800	1120 =	1640 =	1210 =	1540 =
Chromium	MG/KG	17.4	20.9 =*	20.4 =*	20.1 =*	18.3 =*
Cobalt	MG/KG	10.4	15 =*	15.7 =*	8.2 =	9.8 =
Copper	MG/KG	17.7	20.4 J*	18.9 J*	19.8 J*	16.1 J
Iron	MG/KG	23100	30900 =*	28900 =*	29300 =*	28700 =*
Lead	MG/KG	26.1	15 =	15.8 =	14 =	16.2 =
Magnesium	MG/KG	3030	3720 =*	3830 =*	3580 =*	2750 =
Manganese	MG/KG	1450	301 J	336 J	159 J	501 J
Mercury	MG/KG	0.036	0.028 J	0.023 J	0.024 J	0.032 J
Nickel	MG/KG	21.1	25.4 =*	26.3 =*	22.9 =*	18 =
Potassium	MG/KG	927	1260 =*	1490 =*	1340 =*	1210 =*
Selenium	MG/KG	1.4	<2.5 U	<2.6 U	<2.5 U	<2.5 U
Silver	MG/KG		<0.63 U	<0.64 U	<0.63 U	<0.63 U
Sodium	MG/KG	123	<628 U	<640 U	<628 U	<628 U
Thallium	MG/KG		0.17 =*	0.15 =*	0.15 =*	0.14 =*
Vanadium	MG/KG	31.1	26.1 =	26.1 =	24.9 =	24.5 =
Zinc	MG/KG	61.8	58.9 =	56.4 =	54.5 =	68.8 =*

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			Soil	Soil	Soil	Soil
Site			S1/S2	S1/S2	S1/S2	S1/S2
Plot			Plot 092	Plot 110	Plot 190	Plot 037
Sample ID			REF3046	REF3047	REF3048	REF3049
Date			05/09/2002	05/09/2002	05/09/2002	05/09/2002
Depth (ft)			0 - 1	0 - 1	0 - 1	0 - 1
Field Type			Grab	Grab	Grab	Grab
Analyte	Units	RVAAP Site-Wide Background Criteria				
Cyanide	MG/KG		<0.65 U	<0.63 U	<0.64 U	<0.68 U
Aluminum	MG/KG	17700	12100 =	16200 =	13100 =	10000 =
Antimony	MG/KG	0.96	<1.3 UJ	<1.3 UJ	<1.3 UJ	<1.4 UJ
Arsenic	MG/KG	15.4	14 =	10.8 =	12.7 =	10.4 =
Barium	MG/KG	88.4	59.4 =	79.1 =	51.2 =	47.5 =
Beryllium	MG/KG	0.88	0.58 J	0.62 J	0.41 J	0.51 J
Cadmium	MG/KG		<0.65 U	<0.63 U	<0.64 U	<0.68 U
Calcium	MG/KG	15800	1530 =	667 =	473 J	544 J
Chromium	MG/KG	17.4	16.1 =	19.6 =*	16.7 =	13.5 =
Cobalt	MG/KG	10.4	12.2 =*	6.8 =	6.6 =	5.6 =
Copper	MG/KG	17.7	10.2 J	15.9 J	11.6 J	14.2 J
Iron	MG/KG	23100	29200 =*	22800 =	24400 =*	20800 =
Lead	MG/KG	26.1	19.5 =	13.8 =	11.2 =	16.1 =
Magnesium	MG/KG	3030	2280 =	3090 =*	2470 =	2270 =
Manganese	MG/KG	1450	644 J	112 J	211 J	120 J
Mercury	MG/KG	0.036	0.033 J	0.029 J	0.014 J	0.02 J
Nickel	MG/KG	21.1	13.7 =	18.4 =	14.7 =	15.9 =
Potassium	MG/KG	927	1060 =*	1140 =*	1220 =*	981 =*
Selenium	MG/KG	1.4	<2.6 U	<2.5 U	<2.6 U	<2.7 U
Silver	MG/KG		<0.65 U	<0.63 U	<0.64 U	<0.68 U
Sodium	MG/KG	123	<645 U	<628 U	<638 U	<679 U
Thallium	MG/KG		0.13 =*	0.18 =*	0.15 =*	0.14 =*
Vanadium	MG/KG	31.1	24.1 =	22.9 =	21.9 =	17.4 =
Zinc	MG/KG	61.8	54.9 =	61.1 =	44.3 =	52.6 =

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 1
Concentrations of Cyanide and Metals in Soil Samples at Reference Sites

Media			**Soil**	**Soil**	**Soil**
Site			**S1/S2**	**S1/S2**	**S1/S2**
Plot			**Plot 037**	**Plot 147**	**Plot 298**
Sample ID			**REF3056**	**REF3050**	**REF3051**
Date			**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)			**0 - 1**	**0 - 1**	**0 - 1**
Field Type			**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**	**RVAAP Site-Wide Background Criteria**			
Cyanide	MG/KG		<0.65 U	<0.65 U	<0.61 U
Aluminum	MG/KG	17700	11900 =	12500 =	13900 =
Antimony	MG/KG	0.96	<1.3 UJ	<1.3 UJ	<1.2 UJ
Arsenic	MG/KG	15.4	9.2 =	5.7 =	8.3 =
Barium	MG/KG	88.4	90.5 =*	86.3 =	114 =*
Beryllium	MG/KG	0.88	0.67 =	0.69 =	0.86 =
Cadmium	MG/KG		<0.65 U	<0.65 U	<0.61 U
Calcium	MG/KG	15800	1560 =	1570 =	1310 =
Chromium	MG/KG	17.4	17.3 =	16.9 =	20 =*
Cobalt	MG/KG	10.4	11.8 =*	14 =*	36.4 =*
Copper	MG/KG	17.7	20.2 J*	21 J*	22.3 J*
Iron	MG/KG	23100	27300 =*	27800 =*	30400 =*
Lead	MG/KG	26.1	14.7 =	13.7 =	16.2 =
Magnesium	MG/KG	3030	3510 =*	3740 =*	4610 =*
Manganese	MG/KG	1450	383 J	367 J	568 J
Mercury	MG/KG	0.036	0.014 J	0.018 J	0.012 J
Nickel	MG/KG	21.1	28.4 =*	28.3 =*	36.9 =*
Potassium	MG/KG	927	1210 =*	1450 =*	1360 =*
Selenium	MG/KG	1.4	0.46 J	<2.6 U	<2.4 U
Silver	MG/KG		<0.65 U	<0.65 U	<0.61 U
Sodium	MG/KG	123	<653 U	<655 U	<610 U
Thallium	MG/KG		0.14 =*	0.15 =*	0.14 =*
Vanadium	MG/KG	31.1	20.3 =	19.7 =	21.8 =
Zinc	MG/KG	61.8	69 =*	68.4 =*	66.6 =*

*-Exceeds background criteria.
=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**				
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG		<2 U		
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG		<0.25 U		
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**J1/J2**
Plot		**Plot 142**	**Plot 156**	**Plot 173**	**Plot 035**
Sample ID		**REF3035**	**REF3036**	**REF3037**	**REF3038**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**				
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG				
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG				
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 037**	**Plot 108**	**Plot 109**	**Plot 046**
Sample ID		**REF3039**	**REF3040**	**REF3041**	**REF3042**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**				
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG			<2 U	
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG			<0.25 U	
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**S1/S2**
Plot		**Plot 212**	**Plot 249**	**Plot 249**	**Plot 088**
Sample ID		**REF3043**	**REF3044**	**REF3058**	**REF3045**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Field Duplicate**	**Grab**
Analyte	**Units**				
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG				
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG				
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**				
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG				<2 U
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG				<0.25 U
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 2

Concentrations of Explosives and Propellants in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
1,3,5-Trinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U
1,3-Dinitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U
2,4,6-Trinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
2,4-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
2-Amino-4,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
2-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
3-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
4-Amino-2,6-Dinitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
4-Nitrotoluene	MG/KG	<0.25 U	<0.25 U	<0.25 U
HMX	MG/KG	<0.5 U	<0.5 U	<0.5 U
Nitrobenzene	MG/KG	<0.25 U	<0.25 U	<0.25 U
Nitrocellulose	MG/KG	<2 U		
Nitroglycerin	MG/KG	<2.5 U	<2.5 U	<2.5 U
Nitroguanidine	MG/KG	<0.25 U		
RDX	MG/KG	<0.5 U	<0.5 U	<0.5 U
Tetryl	MG/KG	<0.65 U	<0.65 U	<0.65 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,2,4-Trichlorobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
1,2-Dichlorobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
1,3-Dichlorobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
1,4-Dichlorobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,4,5-Trichlorophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,4,6-Trichlorophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,4-Dichlorophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,4-Dimethylphenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,4-Dinitrophenol	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
2,4-Dinitrotoluene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2,6-Dinitrotoluene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2-Chloronaphthalene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2-Chlorophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2-Methyl-4,6-dinitrophenol	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
2-Methylnaphthalene	UG/KG	<410 U	110 J	<390 U	<400 U	140 J
2-Methylphenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
2-Nitrobenzenamine	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
2-Nitrophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
3,3'-Dichlorobenzidine	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
3-Nitrobenzenamine	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
4-Bromophenyl phenyl ether	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
4-Chloro-3-methylphenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
4-Chlorobenzenamine	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
4-Chlorophenyl phenyl ether	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
4-Methylphenol	UG/KG	<410 U	110 J	<390 U	<400 U	110 J
4-Nitrobenzenamine	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
4-Nitrophenol	UG/KG	<990 U	<1000 U	<940 U	<970 U	<970 U
Acenaphthene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Acenaphthylene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Anthracene	UG/KG	<410 U	140 J	<390 U	<400 U	<400 U
Benz(a)anthracene	UG/KG	<410 U	5200 =	<390 U	<400 U	350 J
Benzenemethanol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 3
Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Benzo(a)pyrene	UG/KG	86 J	5500 =	<390 U	<400 U	540 =
Benzo(b)fluoranthene	UG/KG	120 J	10000 =	<390 U	<400 U	740 =
Benzo(ghi)perylene	UG/KG	74 J	3900 =	<390 U	<400 U	440 =
Benzo(k)fluoranthene	UG/KG	<410 U	3800 =	<390 U	<400 U	240 J
Benzoic acid	UG/KG	<2000 UJ	<2000 UJ	<1900 UJ	<1900 UJ	<1900 UJ
Bis(2-chloroethoxy)methane	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Bis(2-chloroethyl) ether	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Bis(2-chloroisopropyl) ether	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Bis(2-ethylhexyl)phthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	70 J
Butyl benzyl phthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Carbazole	UG/KG	<410 U	170 J	<390 U	<400 U	<400 U
Chrysene	UG/KG	58 J	8200 =	<390 U	<400 U	450 =
Di-n-butyl phthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Di-n-octylphthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Dibenz(a,h)anthracene	UG/KG	<410 U	1000 =	<390 U	<400 U	100 J
Dibenzofuran	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Diethyl phthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Dimethyl phthalate	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Fluoranthene	UG/KG	<410 U	10000 =	<390 U	<400 U	460 =
Fluorene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Hexachlorobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Hexachlorobutadiene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Hexachlorocyclopentadiene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Hexachloroethane	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Indeno(1,2,3-cd)pyrene	UG/KG	<410 U	3600 =	<390 U	<400 U	370 J
Isophorone	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
N-Nitroso-di-n-propylamine	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
N-Nitrosodiphenylamine	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Naphthalene	UG/KG	<410 U	110 J	<390 U	<400 U	120 J
Nitrobenzene	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Pentachlorophenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Phenanthrene	UG/KG	<410 U	550 =	<390 U	<400 U	200 J

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Phenol	UG/KG	<410 U	<420 U	<390 U	<400 U	<400 U
Pyrene	UG/KG	<410 U	5200 =	<390 U	<400 U	450 =

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,2,4-Trichlorobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
1,2-Dichlorobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
1,3-Dichlorobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
1,4-Dichlorobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,4,5-Trichlorophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,4,6-Trichlorophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,4-Dichlorophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,4-Dimethylphenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,4-Dinitrophenol	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
2,4-Dinitrotoluene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2,6-Dinitrotoluene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2-Chloronaphthalene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2-Chlorophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2-Methyl-4,6-dinitrophenol	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
2-Methylnaphthalene	UG/KG	<400 U	120 J	<410 U	<440 U	<410 U
2-Methylphenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
2-Nitrobenzenamine	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
2-Nitrophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
3,3'-Dichlorobenzidine	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
3-Nitrobenzenamine	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
4-Bromophenyl phenyl ether	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
4-Chloro-3-methylphenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
4-Chlorobenzenamine	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
4-Chlorophenyl phenyl ether	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
4-Methylphenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
4-Nitrobenzenamine	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
4-Nitrophenol	UG/KG	<980 U	<1000 U	<1000 U	<1100 U	<990 U
Acenaphthene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Acenaphthylene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Anthracene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Benz(a)anthracene	UG/KG	150 J	260 J	<410 U	<440 U	<410 U
Benzenemethanol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 3
Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Benzo(a)pyrene	UG/KG	210 J	340 J	<410 U	<440 U	<410 U
Benzo(b)fluoranthene	UG/KG	290 J	450 =	<410 U	<440 U	<410 U
Benzo(ghi)perylene	UG/KG	170 J	290 J	<410 U	<440 U	<410 U
Benzo(k)fluoranthene	UG/KG	110 J	220 J	<410 U	<440 U	<410 U
Benzoic acid	UG/KG	<2000 UJ	<2000 UJ	<2000 UJ	<2200 UJ	<2000 UJ
Bis(2-chloroethoxy)methane	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Bis(2-chloroethyl) ether	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Bis(2-chloroisopropyl) ether	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Bis(2-ethylhexyl)phthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Butyl benzyl phthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Carbazole	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Chrysene	UG/KG	190 J	300 J	<410 U	<440 U	<410 U
Di-n-butyl phthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Di-n-octylphthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Dibenz(a,h)anthracene	UG/KG	<400 U	76 J	<410 U	<440 U	<410 U
Dibenzofuran	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Diethyl phthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Dimethyl phthalate	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Fluoranthene	UG/KG	220 J	390 J	<410 U	85 J	<410 U
Fluorene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Hexachlorobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Hexachlorobutadiene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Hexachlorocyclopentadiene	UG/KG	<400 U	<410 R	<410 U	<440 U	<410 U
Hexachloroethane	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Indeno(1,2,3-cd)pyrene	UG/KG	140 J	240 J	<410 U	<440 U	<410 U
Isophorone	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
N-Nitroso-di-n-propylamine	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
N-Nitrosodiphenylamine	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Naphthalene	UG/KG	<400 U	110 J	<410 U	<440 U	<410 U
Nitrobenzene	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Pentachlorophenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Phenanthrene	UG/KG	96 J	170 J	<410 U	<440 U	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Phenol	UG/KG	<400 U	<410 U	<410 U	<440 U	<410 U
Pyrene	UG/KG	210 J	320 J	<410 U	69 J	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 3
Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
1,2,4-Trichlorobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
1,2-Dichlorobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
1,3-Dichlorobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
1,4-Dichlorobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,4,5-Trichlorophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,4,6-Trichlorophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,4-Dichlorophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,4-Dimethylphenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,4-Dinitrophenol	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
2,4-Dinitrotoluene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2,6-Dinitrotoluene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2-Chloronaphthalene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2-Chlorophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2-Methyl-4,6-dinitrophenol	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
2-Methylnaphthalene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2-Methylphenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
2-Nitrobenzenamine	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
2-Nitrophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
3,3'-Dichlorobenzidine	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
3-Nitrobenzenamine	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
4-Bromophenyl phenyl ether	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
4-Chloro-3-methylphenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
4-Chlorobenzenamine	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
4-Chlorophenyl phenyl ether	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
4-Methylphenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
4-Nitrobenzenamine	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
4-Nitrophenol	UG/KG	<1000 U	<1100 U	<1000 U	<1000 U	<1000 U
Acenaphthene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Acenaphthylene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Anthracene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benz(a)anthracene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benzenemethanol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 3
Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
Benzo(a)pyrene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benzo(b)fluoranthene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benzo(ghi)perylene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benzo(k)fluoranthene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Benzoic acid	UG/KG	<2000 UJ	190 J	<2000 UJ	<2000 UJ	<2000 UJ
Bis(2-chloroethoxy)methane	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Bis(2-chloroethyl) ether	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Bis(2-chloroisopropyl) ether	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Bis(2-ethylhexyl)phthalate	UG/KG	71 J	130 J	<410 U	<420 U	<410 U
Butyl benzyl phthalate	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Carbazole	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Chrysene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Di-n-butyl phthalate	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Di-n-octylphthalate	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Dibenz(a,h)anthracene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Dibenzofuran	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Diethyl phthalate	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Dimethyl phthalate	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Fluoranthene	UG/KG	<410 U	74 J	<410 U	<420 U	<410 U
Fluorene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Hexachlorobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Hexachlorobutadiene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Hexachlorocyclopentadiene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Hexachloroethane	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Indeno(1,2,3-cd)pyrene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Isophorone	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
N-Nitroso-di-n-propylamine	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
N-Nitrosodiphenylamine	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Naphthalene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Nitrobenzene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Pentachlorophenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Phenanthrene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
Phenol	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U
Pyrene	UG/KG	<410 U	<440 U	<410 U	<420 U	<410 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,2,4-Trichlorobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
1,2-Dichlorobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
1,3-Dichlorobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
1,4-Dichlorobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,4,5-Trichlorophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,4,6-Trichlorophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,4-Dichlorophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,4-Dimethylphenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,4-Dinitrophenol	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
2,4-Dinitrotoluene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2,6-Dinitrotoluene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2-Chloronaphthalene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2-Chlorophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2-Methyl-4,6-dinitrophenol	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
2-Methylnaphthalene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2-Methylphenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
2-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
2-Nitrophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
3,3'-Dichlorobenzidine	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
3-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
4-Bromophenyl phenyl ether	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
4-Chloro-3-methylphenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
4-Chlorobenzenamine	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
4-Chlorophenyl phenyl ether	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
4-Methylphenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
4-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
4-Nitrophenol	UG/KG	<1000 U	<1000 U	<1000 U	<1000 U	<1100 U
Acenaphthene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Acenaphthylene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Anthracene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benz(a)anthracene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benzenemethanol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Benzo(a)pyrene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benzo(b)fluoranthene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benzo(ghi)perylene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benzo(k)fluoranthene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Benzoic acid	UG/KG	<2000 UJ	230 J	<2000 UJ	<2000 UJ	<2200 UJ
Bis(2-chloroethoxy)methane	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Bis(2-chloroethyl) ether	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Bis(2-chloroisopropyl) ether	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Bis(2-ethylhexyl)phthalate	UG/KG	<410 U	<430 U	<410 U	93 J	<450 U
Butyl benzyl phthalate	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Carbazole	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Chrysene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Di-n-butyl phthalate	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Di-n-octylphthalate	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Dibenz(a,h)anthracene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Dibenzofuran	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Diethyl phthalate	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Dimethyl phthalate	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Fluoranthene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Fluorene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Hexachlorobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Hexachlorobutadiene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Hexachlorocyclopentadiene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Hexachloroethane	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Indeno(1,2,3-cd)pyrene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Isophorone	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
N-Nitroso-di-n-propylamine	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
N-Nitrosodiphenylamine	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Naphthalene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Nitrobenzene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Pentachlorophenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Phenanthrene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Phenol	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U
Pyrene	UG/KG	<410 U	<430 U	<410 U	<420 U	<450 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
1,2,4-Trichlorobenzene	UG/KG	<430 U	<430 U	<400 U
1,2-Dichlorobenzene	UG/KG	<430 U	<430 U	<400 U
1,3-Dichlorobenzene	UG/KG	<430 U	<430 U	<400 U
1,4-Dichlorobenzene	UG/KG	<430 U	<430 U	<400 U
2,4,5-Trichlorophenol	UG/KG	<430 U	<430 U	<400 U
2,4,6-Trichlorophenol	UG/KG	<430 U	<430 U	<400 U
2,4-Dichlorophenol	UG/KG	<430 U	<430 U	<400 U
2,4-Dimethylphenol	UG/KG	<430 U	<430 U	<400 U
2,4-Dinitrophenol	UG/KG	<1000 U	<1000 U	<980 U
2,4-Dinitrotoluene	UG/KG	<430 U	<430 U	<400 U
2,6-Dinitrotoluene	UG/KG	<430 U	<430 U	<400 U
2-Chloronaphthalene	UG/KG	<430 U	<430 U	<400 U
2-Chlorophenol	UG/KG	<430 U	<430 U	<400 U
2-Methyl-4,6-dinitrophenol	UG/KG	<1000 U	<1000 U	<980 U
2-Methylnaphthalene	UG/KG	<430 U	<430 U	<400 U
2-Methylphenol	UG/KG	<430 U	<430 U	<400 U
2-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<980 U
2-Nitrophenol	UG/KG	<430 U	<430 U	<400 U
3,3'-Dichlorobenzidine	UG/KG	<430 U	<430 U	<400 U
3-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<980 U
4-Bromophenyl phenyl ether	UG/KG	<430 U	<430 U	<400 U
4-Chloro-3-methylphenol	UG/KG	<430 U	<430 U	<400 U
4-Chlorobenzenamine	UG/KG	<430 U	<430 U	<400 U
4-Chlorophenyl phenyl ether	UG/KG	<430 U	<430 U	<400 U
4-Methylphenol	UG/KG	<430 U	<430 U	<400 U
4-Nitrobenzenamine	UG/KG	<1000 U	<1000 U	<980 U
4-Nitrophenol	UG/KG	<1000 U	<1000 U	<980 U
Acenaphthene	UG/KG	<430 U	<430 U	<400 U
Acenaphthylene	UG/KG	<430 U	<430 U	<400 U
Anthracene	UG/KG	<430 U	<430 U	<400 U
Benz(a)anthracene	UG/KG	<430 U	<430 U	<400 U
Benzenemethanol	UG/KG	<430 U	<430 U	<400 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
Benzo(a)pyrene	UG/KG	<430 U	<430 U	<400 U
Benzo(b)fluoranthene	UG/KG	<430 U	<430 U	<400 U
Benzo(ghi)perylene	UG/KG	<430 U	<430 U	<400 U
Benzo(k)fluoranthene	UG/KG	<430 U	<430 U	<400 U
Benzoic acid	UG/KG	<2100 UJ	<2100 UJ	<2000 UJ
Bis(2-chloroethoxy)methane	UG/KG	<430 U	<430 U	<400 U
Bis(2-chloroethyl) ether	UG/KG	<430 U	<430 U	<400 U
Bis(2-chloroisopropyl) ether	UG/KG	<430 U	<430 U	<400 U
Bis(2-ethylhexyl)phthalate	UG/KG	<430 U	<430 U	<400 U
Butyl benzyl phthalate	UG/KG	<430 U	<430 U	<400 U
Carbazole	UG/KG	<430 U	<430 U	<400 U
Chrysene	UG/KG	<430 U	<430 U	<400 U
Di-n-butyl phthalate	UG/KG	<430 U	<430 U	<400 U
Di-n-octylphthalate	UG/KG	<430 U	<430 U	<400 U
Dibenz(a,h)anthracene	UG/KG	<430 U	<430 U	<400 U
Dibenzofuran	UG/KG	<430 U	<430 U	<400 U
Diethyl phthalate	UG/KG	<430 U	<430 U	<400 U
Dimethyl phthalate	UG/KG	<430 U	<430 U	<400 U
Fluoranthene	UG/KG	<430 U	<430 U	<400 U
Fluorene	UG/KG	<430 U	<430 U	<400 U
Hexachlorobenzene	UG/KG	<430 U	<430 U	<400 U
Hexachlorobutadiene	UG/KG	<430 U	<430 U	<400 U
Hexachlorocyclopentadiene	UG/KG	<430 U	<430 U	<400 U
Hexachloroethane	UG/KG	<430 U	<430 U	<400 U
Indeno(1,2,3-cd)pyrene	UG/KG	<430 U	<430 U	<400 U
Isophorone	UG/KG	<430 U	<430 U	<400 U
N-Nitroso-di-n-propylamine	UG/KG	<430 U	<430 U	<400 U
N-Nitrosodiphenylamine	UG/KG	<430 U	<430 U	<400 U
Naphthalene	UG/KG	<430 U	<430 U	<400 U
Nitrobenzene	UG/KG	<430 U	<430 U	<400 U
Pentachlorophenol	UG/KG	<430 U	<430 U	<400 U
Phenanthrene	UG/KG	<430 U	<430 U	<400 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 3

Concentrations of Semivolatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
Phenol	UG/KG	<430 U	<430 U	<400 U
Pyrene	UG/KG	<430 U	<430 U	<400 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,1,1-Trichloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,1,2,2-Tetrachloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,1,2-Trichloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,1-Dichloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,1-Dichloroethene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,2-Dibromoethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,2-Dichloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,2-Dichloroethene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
1,2-Dichloropropane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
2-Butanone	UG/KG	<25 U	<26 U	<23 U	<24 U	<24 U
2-Hexanone	UG/KG	<25 U	<26 U	<23 U	<24 U	<24 U
4-Methyl-2-pentanone	UG/KG	<25 U	<26 U	<23 U	<24 U	<24 U
Acetone	UG/KG	<25 U	<26 U	<23 U	<24 U	<24 U
Benzene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Bromochloromethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Bromodichloromethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Bromoform	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Bromomethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Carbon disulfide	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Carbon tetrachloride	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Chlorobenzene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Chloroethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Chloroform	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Chloromethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Dibromochloromethane	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Dimethylbenzene	UG/KG	2.9 J	13 =	4 J	2.5 J	6.8 =
Ethylbenzene	UG/KG	<6.2 U	3 J	<5.9 U	<6.1 U	1.6 J
Methylene chloride	UG/KG	<6.2 U	7.2 =	<5.9 U	<6.1 U	9.1 =
Styrene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
Tetrachloroethene	UG/KG	<6.2 U	2.4 J	<5.9 U	<6.1 U	2.2 J
Toluene	UG/KG	<6.2 U	1.9 J	<5.9 U	<6.1 U	3.9 J
Trichloroethene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Vinyl chloride	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
cis-1,3-Dichloropropene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U
trans-1,3-Dichloropropene	UG/KG	<6.2 U	<6.4 U	<5.9 U	<6.1 U	<6.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 4
Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,1,1-Trichloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,1,2,2-Tetrachloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,1,2-Trichloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,1-Dichloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,1-Dichloroethene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,2-Dibromoethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,2-Dichloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,2-Dichloroethene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
1,2-Dichloropropane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
2-Butanone	UG/KG	<24 U	<25 U	<25 U	<27 U	<25 U
2-Hexanone	UG/KG	<24 U	<25 U	<25 U	<27 U	<25 U
4-Methyl-2-pentanone	UG/KG	<24 U	<25 U	<25 U	<27 U	<25 U
Acetone	UG/KG	<24 U	<25 U	<25 U	<27 U	<25 U
Benzene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Bromochloromethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Bromodichloromethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Bromoform	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Bromomethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Carbon disulfide	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Carbon tetrachloride	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Chlorobenzene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Chloroethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Chloroform	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Chloromethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Dibromochloromethane	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Dimethylbenzene	UG/KG	5.5 J	7 =	<6.3 U	<6.7 U	6.5 =
Ethylbenzene	UG/KG	0.82 J	1.5 J	<6.3 U	<6.7 U	1.1 J
Methylene chloride	UG/KG	2.3 J	2.3 J	<6.3 U	<6.7 U	<6.2 U
Styrene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Tetrachloroethene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
Toluene	UG/KG	1.6 J	0.96 J	<6.3 U	<6.7 U	<6.2 U
Trichloroethene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Vinyl chloride	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
cis-1,3-Dichloropropene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U
trans-1,3-Dichloropropene	UG/KG	<6.1 U	<6.2 U	<6.3 U	<6.7 U	<6.2 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 4
Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
1,1,1-Trichloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,1,2,2-Tetrachloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,1,2-Trichloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,1-Dichloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,1-Dichloroethene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,2-Dibromoethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,2-Dichloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,2-Dichloroethene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
1,2-Dichloropropane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
2-Butanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<25 U
2-Hexanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<25 U
4-Methyl-2-pentanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<25 U
Acetone	UG/KG	<25 U	<26 U	<25 U	<26 U	<25 U
Benzene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Bromochloromethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Bromodichloromethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Bromoform	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Bromomethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Carbon disulfide	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Carbon tetrachloride	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Chlorobenzene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Chloroethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Chloroform	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Chloromethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Dibromochloromethane	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Dimethylbenzene	UG/KG	2.7 J	2.9 J	3.7 J	<6.4 U	3.5 J
Ethylbenzene	UG/KG	<6.3 U	<6.6 U	0.76 J	<6.4 U	<6.3 U
Methylene chloride	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	2.2 J
Styrene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Tetrachloroethene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
Toluene	UG/KG	<6.3 U	<6.6 U	<6.3 U	0.98 J	3.3 J
Trichloroethene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
Vinyl chloride	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
cis-1,3-Dichloropropene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U
trans-1,3-Dichloropropene	UG/KG	<6.3 U	<6.6 U	<6.3 U	<6.4 U	<6.3 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 4
Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
1,1,1-Trichloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,1,2,2-Tetrachloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,1,2-Trichloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,1-Dichloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,1-Dichloroethene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,2-Dibromoethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,2-Dichloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,2-Dichloroethene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
1,2-Dichloropropane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
2-Butanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<27 U
2-Hexanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<27 U
4-Methyl-2-pentanone	UG/KG	<25 U	<26 U	<25 U	<26 U	<27 U
Acetone	UG/KG	<25 U	<26 U	<25 U	<26 U	<27 U
Benzene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Bromochloromethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Bromodichloromethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Bromoform	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Bromomethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Carbon disulfide	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Carbon tetrachloride	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Chlorobenzene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Chloroethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Chloroform	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Chloromethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Dibromochloromethane	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Dimethylbenzene	UG/KG	<6.3 U	<6.5 U	2.7 J	<6.4 U	<6.8 U
Ethylbenzene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Methylene chloride	UG/KG	<6.3 U	1.8 J	<6.3 U	<6.4 U	<6.8 U
Styrene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Tetrachloroethene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
Toluene	UG/KG	1.4 J	<6.5 U	1.7 J	2 J	<6.8 U
Trichloroethene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
Vinyl chloride	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
cis-1,3-Dichloropropene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U
trans-1,3-Dichloropropene	UG/KG	<6.3 U	<6.5 U	<6.3 U	<6.4 U	<6.8 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 4
Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
1,1,1-Trichloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,1,2,2-Tetrachloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,1,2-Trichloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,1-Dichloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,1-Dichloroethene	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,2-Dibromoethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,2-Dichloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,2-Dichloroethene	UG/KG	<6.5 U	<6.5 U	<6.1 U
1,2-Dichloropropane	UG/KG	<6.5 U	<6.5 U	<6.1 U
2-Butanone	UG/KG	<26 U	<26 U	<24 U
2-Hexanone	UG/KG	<26 U	<26 U	<24 U
4-Methyl-2-pentanone	UG/KG	<26 U	<26 U	<24 U
Acetone	UG/KG	<26 U	<26 U	<24 U
Benzene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Bromochloromethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Bromodichloromethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Bromoform	UG/KG	<6.5 U	<6.5 U	<6.1 U
Bromomethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Carbon disulfide	UG/KG	<6.5 U	<6.5 U	<6.1 U
Carbon tetrachloride	UG/KG	<6.5 U	<6.5 U	<6.1 U
Chlorobenzene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Chloroethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Chloroform	UG/KG	<6.5 U	<6.5 U	<6.1 U
Chloromethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Dibromochloromethane	UG/KG	<6.5 U	<6.5 U	<6.1 U
Dimethylbenzene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Ethylbenzene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Methylene chloride	UG/KG	<6.5 U	<6.5 U	<6.1 U
Styrene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Tetrachloroethene	UG/KG	<6.5 U	<6.5 U	<6.1 U
Toluene	UG/KG	<6.5 U	<6.5 U	0.81 J
Trichloroethene	UG/KG	<6.5 U	<6.5 U	<6.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 4

Concentrations of Volatile Organics in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
Vinyl chloride	UG/KG	<6.5 U	<6.5 U	<6.1 U
cis-1,3-Dichloropropene	UG/KG	<6.5 U	<6.5 U	<6.1 U
trans-1,3-Dichloropropene	UG/KG	<6.5 U	<6.5 U	<6.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 5

Concentrations of Pesticides and PCBs in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**	**E1/E2**
Plot		**Plot 146**	**Plot 154**	**Plot 223**	**Plot 007**	**Plot 142**
Sample ID		**REF3031**	**REF3032**	**REF3033**	**REF3034**	**REF3035**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
4,4'-DDD	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
4,4'-DDE	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
4,4'-DDT	UG/KG	<2.1 UJ	<2.2 U	<2 UJ	<2.1 UJ	<2.1 U
Aldrin	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Dieldrin	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endosulfan I	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endosulfan II	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endosulfan sulfate	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endrin	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endrin aldehyde	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Endrin ketone	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Heptachlor	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Heptachlor epoxide	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Lindane	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
Methoxychlor	UG/KG	<4.1 U	<4.2 U	<3.9 UJ	<4 U	<4 U
PCB-1016	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1221	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1232	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1242	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1248	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1254	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
PCB-1260	UG/KG	<41 U	<42 U	<39 U	<40 U	<40 U
Toxaphene	UG/KG	<83 U	<86 U	<78 U	<81 U	<81 U
alpha-BHC	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
alpha-Chlordane	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
beta-BHC	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
delta-BHC	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U
gamma-Chlordane	UG/KG	<2.1 U	<2.2 U	<2 U	<2.1 U	<2.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 5

Concentrations of Pesticides and PCBs in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**E1/E2**	**E1/E2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 156**	**Plot 173**	**Plot 035**	**Plot 037**	**Plot 108**
Sample ID		**REF3036**	**REF3037**	**REF3038**	**REF3039**	**REF3040**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
4,4'-DDD	UG/KG	<2.1 U	<2.1 R	<2.1 U	<2.3 U	<2.1 U
4,4'-DDE	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
4,4'-DDT	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 UJ
Aldrin	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Dieldrin	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Endosulfan I	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Endosulfan II	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Endosulfan sulfate	UG/KG	<2.1 U	<2.1 R	<2.1 U	<2.3 U	<2.1 U
Endrin	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Endrin aldehyde	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Endrin ketone	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Heptachlor	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Heptachlor epoxide	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Lindane	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
Methoxychlor	UG/KG	<4 U	<4.1 U	<4.1 U	<4.4 U	<4.1 U
PCB-1016	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1221	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1232	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1242	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1248	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1254	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
PCB-1260	UG/KG	<40 U	<41 U	<41 U	<44 U	<41 U
Toxaphene	UG/KG	<82 U	<84 U	<84 U	<90 U	<83 U
alpha-BHC	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
alpha-Chlordane	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
beta-BHC	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U
delta-BHC	UG/KG	<2.1 U	<2.1 R	<2.1 U	<2.3 U	<2.1 U
gamma-Chlordane	UG/KG	<2.1 U	<2.1 U	<2.1 U	<2.3 U	<2.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 5

Concentrations of Pesticides and PCBs in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**	**J1/J2**
Plot		**Plot 109**	**Plot 046**	**Plot 212**	**Plot 249**	**Plot 249**
Sample ID		**REF3041**	**REF3042**	**REF3043**	**REF3044**	**REF3058**
Date		**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**	**05/10/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Field Duplicate**
Analyte	**Units**					
4,4'-DDD	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
4,4'-DDE	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
4,4'-DDT	UG/KG	<2.1 UJ	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Aldrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Dieldrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endosulfan I	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endosulfan II	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endosulfan sulfate	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endrin aldehyde	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Endrin ketone	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Heptachlor	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Heptachlor epoxide	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Lindane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
Methoxychlor	UG/KG	<4.1 U	<4.4 U	<4.1 U	<4.2 U	<4.1 U
PCB-1016	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1221	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1232	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1242	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1248	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1254	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
PCB-1260	UG/KG	<41 U	<44 U	<41 U	<42 U	<41 U
Toxaphene	UG/KG	<84 U	<89 U	<84 U	<86 U	<84 U
alpha-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
alpha-Chlordane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
beta-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
delta-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U
gamma-Chlordane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1

Table 5

Concentrations of Pesticides and PCBs in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 088**	**Plot 092**	**Plot 110**	**Plot 190**	**Plot 037**
Sample ID		**REF3045**	**REF3046**	**REF3047**	**REF3048**	**REF3049**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte	**Units**					
4,4'-DDD	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
4,4'-DDE	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
4,4'-DDT	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Aldrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Dieldrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endosulfan I	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endosulfan II	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endosulfan sulfate	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endrin	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endrin aldehyde	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Endrin ketone	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Heptachlor	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Heptachlor epoxide	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Lindane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
Methoxychlor	UG/KG	<4.1 U	<4.3 U	<4.1 U	<4.2 U	<4.5 U
PCB-1016	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1221	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1232	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1242	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1248	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1254	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
PCB-1260	UG/KG	<41 U	<43 U	<41 U	<42 U	<45 U
Toxaphene	UG/KG	<84 U	<86 U	<84 U	<85 U	<91 U
alpha-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
alpha-Chlordane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
beta-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
delta-BHC	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U
gamma-Chlordane	UG/KG	<2.1 U	<2.2 U	<2.1 U	<2.2 U	<2.3 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

Attachment 1
Table 5
Concentrations of Pesticides and PCBs in Soil Samples at Reference Sites

Media		**Soil**	**Soil**	**Soil**
Site		**S1/S2**	**S1/S2**	**S1/S2**
Plot		**Plot 037**	**Plot 147**	**Plot 298**
Sample ID		**REF3056**	**REF3050**	**REF3051**
Date		**05/09/2002**	**05/09/2002**	**05/09/2002**
Depth (ft)		**0 - 1**	**0 - 1**	**0 - 1**
Field Type		**Field Duplicate**	**Grab**	**Grab**
Analyte	**Units**			
4,4'-DDD	UG/KG	<2.2 U	<2.2 U	<2.1 U
4,4'-DDE	UG/KG	<2.2 U	<2.2 U	<2.1 U
4,4'-DDT	UG/KG	<2.2 U	<2.2 U	<2.1 U
Aldrin	UG/KG	<2.2 U	<2.2 U	<2.1 U
Dieldrin	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endosulfan I	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endosulfan II	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endosulfan sulfate	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endrin	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endrin aldehyde	UG/KG	<2.2 U	<2.2 U	<2.1 U
Endrin ketone	UG/KG	<2.2 U	<2.2 U	<2.1 U
Heptachlor	UG/KG	<2.2 U	<2.2 U	<2.1 U
Heptachlor epoxide	UG/KG	<2.2 U	<2.2 U	<2.1 U
Lindane	UG/KG	<2.2 U	<2.2 U	<2.1 U
Methoxychlor	UG/KG	<4.3 U	<4.3 U	<4 U
PCB-1016	UG/KG	<43 U	<43 U	<40 U
PCB-1221	UG/KG	<43 U	<43 U	<40 U
PCB-1232	UG/KG	<43 U	<43 U	<40 U
PCB-1242	UG/KG	<43 U	<43 U	<40 U
PCB-1248	UG/KG	<43 U	<43 U	<40 U
PCB-1254	UG/KG	<43 U	<43 U	<40 U
PCB-1260	UG/KG	<43 U	<43 U	<40 U
Toxaphene	UG/KG	<88 U	<88 U	<82 U
alpha-BHC	UG/KG	<2.2 U	<2.2 U	<2.1 U
alpha-Chlordane	UG/KG	<2.2 U	<2.2 U	<2.1 U
beta-BHC	UG/KG	<2.2 U	<2.2 U	<2.1 U
delta-BHC	UG/KG	<2.2 U	<2.2 U	<2.1 U
gamma-Chlordane	UG/KG	<2.2 U	<2.2 U	<2.1 U

=- detected.
U-not detected.
J-estimated.
UJ-not detected, estimated detection limit.

5.0 RE-SCREEN OF HAZARD QUOTIENTS

5.1 RE-SCREEN RATIONALE

At the time that the WBG Phase II RI report (SAIC 2001) containing the ERA was scoped and produced, the RVAAP team agreed to move forward using the EPA guidance for screening-level ERA (EPA 1998) HQs. The intent of the screening-level ERA was to identify plant, soil invertebrate, mammal, and bird receptors, as well as burn pads, within WBG that were of particular concern. The screening values for the ecological receptors were to be selected from very conservative, albeit commonly used, databases. When the screening HQs were calculated for 70 WBG burning pad sites, most exceeded the threshold value of one. HQs, based on the maximum concentration of the chemicals on each pad and conservative assumptions (i.e. no diet adjustment, 100% area use factor), were calculated to be in the range of 100s or 1000s for receptors, particularly plants, birds, and small mammals, susceptible to metals and explosives in the soils. Thus, the screening-level ERA served its purpose of showing which receptors, which chemicals, and which pads were of greatest potential concern. Based on EPA guidance (1998) and professional experience with such high HQ values, RVAAP risk managers and risk assessors agreed that a site-specific field study was a beneficial use of resources to allow for risk management decisions instead of further iterations of desktop risk modeling.

In the amount of time that was required for planning and performing the field investigation, there was significant advancement of ecological risk assessment and management methodologies. New developments included modifications in the HQ calculation that would allow for more realistic exposures and newly developed screening values. Given this new information, it was decided to re-screen the data as an additional line of evidence for risk management and for the report. Although not a typical step in ecological risk assessment, it was agreed that the sites at WBG selected for field study based on predicted impact from the initial screen (36, 37, 58,59, and 66, 67) could be re-screened and the results included in this report. Use of the representative screening values and more realistic exposure parameters and representative toxicity reference values (TRVs) has a dramatic effect on the screening HQs at the selected WBG pad sites (Tables 5-1 through 5-3). Although not all of the screening HQ values were decreased below the threshold of one, the newly calculated screening HQs rarely exceeded 100. The re-screen calculations of the HQs again served the purpose of the screening-level ERA by indicating the receptors, chemicals, and locations of greatest potential ecological concern. The newly calculated screening HQs, although still indicating potential concern, more closely identify with the visual observations of the site, the indications of the various Ohio National Guard ecological surveys, and the results of the WBG biological measures field effort.

Also during the period of time for planning and performing the field study and preparation of this report, the EPA published a soil screening guidance with a new risk policy on aluminum in soil (USEPA, Draft Guidance for Ecological Soil Screening Levels (Eco-SSLs), 1999). A compilation of studies provided evidence that aluminum was not bioavailable to ecological receptors in soil conditions where the pH was greater than 5.5. The lack of bioavailability reduces the uptake of the element and reduces toxicity to both human and ecological receptors. The upland soils at RVAAP and particularly at WBG are known to have a pH much closer to neutral, thus reducing the soluble aluminum concentration. The screening HQs for aluminum were very high for most ecological receptors at both the study areas and the reference sites; however, according to the new guidance, they can be qualitatively dismissed in further risk management decisions.

The results of the re-screening might have impacted the decision of the RVAAP risk team (risk assessors and risk managers) to move ahead into a field study if the results of the studies were to only be applied at the WBG. A holistic interpretation of the data at WBG would likely indicate that the AOC as a whole

might not be impacted. The initial plan for the study, however, was to extrapolate as much quality information as possible to other AOCs at RVAAP where field studies would not be feasible. The WBG was considered to be one of the best places to carry out a field study, as mentioned previously in this document, for the high concentrations of contaminants and quality of habitat. Also, there is argument that the re-screen HQs of the pads were of the magnitude to require further investigation versus a management decision based solely on HQ results.

5.2 RE-SCREEN METHODOLOGY

In order to perform the re-screen of the WBG data for pad pairs 37/38, 58/59, and 66/67, the analytical chemical data from the pad pairs were combined into one data set. A 95% UCL was calculated using the Model Toxics Control Act statistical program. The MTCA program automatically investigates the data set to determine the most appropriate statistical methodology for calculating the 95% UCL. If the data are found to be normally distributed, the program will develop the 95% UCL from the t-statistic. If the data are lognormal, the program will select between the use of the parametric H-statistic or the non-parametric Z-statistic. Use of the Z-statistic is not typical based on EPA guidance; however, use of the H-statistic as the only method for UCL development has been noted as problematic (EPA 1998). Use of the Z-statistic methodology for calculating the 95% UCL is not typical for the remainder of this report; however, the results are considered to be at least comparable to those of the more commonly used H-statistic approach.

The updated screening TRVs were selected from publications from the Oak Ridge National Laboratory (ORNL) [Efroymson et al. 1997a,b,c] and are presented in Tables 5-1 through 5-9. The values not available from the ORNL database were supplemented by the EPA Region 5 Ecological Data Quality Level (EDQL) values (EPA n.d.). This was particularly important for the explosives TRVs.

5.3 RESULTS

Tables 5-1 through 5-9 present the results of the simple HQ ratio for the maximum concentration, the 95% UCL, and the arithmetic mean of the analytes for the combined pad pairs. Results are provided by pad pairs: 37 and 38, 58 and 59, and 66 and 67. Results are provided for general life forms, plants, and small mammals.

TABLES

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Table 5-1. Pad 37 and 38 General Screening Recalculation

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[e]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0	0.23	2.8	0.682	Z-stat	0.46					
Aluminum	17700	9750	30700	17941.17	Z-stat	16413.64	50	Plant	614	358.82	328.27
Antimony	0.96	0.15	6.1	1.81	Land's	1.35	5	Plant	1.22	0.36	0.27
Arsenic	15.4	0.31	25.6	13.39	t-stat	11.52	9.9	Shrew/plant	2.59	1.35	1.16
Barium	88.4	54.8	596	193.44	Z-stat	154.72	283	Woodcock	2.11	0.68	0.55
Beryllium	0.88	0.17	10.9	2.18	Z-stat	1.43	10	Plant	1.09	0.22	0.14
Cadmium	0	0.073	877	71.2	Land's	34.24	4	Plant	219.25	17.80	8.56
Calcium	15800	637	247000	121863.25	Land's	35738					
Chromium	17.4	3.4	37.6	21.45	t-stat	19.5	0.4	Earthworm	94	53.63	48.75
Cobalt	10.4	0.92	11.5	8.41	t-stat	7.68	20	Plant	0.58	0.42	0.38
Copper	17.7	0.32	491	67.99	Z-stat	39.93	60	Earthworm	8.18	1.13	0.67
Iron	23100	1350	31800	24539.89	Z-stat	22115					
Lead	26.1	0.15	1490	216.95	Z-stat	137.01	40.5	Woodcock	36.79	5.36	3.38
Magnesium	3030	1520	53700	12134.635	Z-stat	8148.93					
Manganese	1450	278	4270	1258.65	Land's	1017.36					
Mercury	0.04	0.015	0.941	0.108	Z-stat	0.06	0.00051	Woodcock	1845.10	211.76	117.65
Nickel	21.1	4	23.9	17.44	t-stat	15.79	30	Plant	0.80	0.58	0.53
Potassium	927	606	3710	1742.63	Land's	1519.36					
Selenium	1.4	0.29	5	1.45	Land's	1.16	0.21	Mouse	23.81	6.90	5.52
Silver	0	0.1	1.5	0.657	Z-stat	0.58	2	Plant	0.75	0.33	0.29
Sodium	123	23.7	2320	735.46	Land's	385.73					
Thallium	0	0.061	2.7	0.66	Z-stat	0.52	1	Plant	2.7	0.66	0.52
Vanadium	31.1	4.9	31	24.1	t-stat	22.16	2	Plant	15.5	12.05	11.08
Zinc	61.8	1	877	199.68	Z-stat	152.8	8.5	Woodcock	103.18	23.49	17.98
1,3,5-Trinitrobenzene		0.057	0.62	0.19	Z-stat	0.15	0.376	EDQL	1.65	0.51	0.40
1,3-Dinitrobenzene		0.088	0.25	0.14	Z-stat	0.13	0.655	EDQL	0.38	0.21	0.20
2,4,6-Trinitrotoluene		0.061	580	74.386	Z-stat	29.05	140	EDQL	4.14	0.53	0.21
2,4-Dinitrotoluene		0.063	0.31	0.202	Z-stat	0.18	1.28	EDQL	0.24	0.16	0.14
2,6-Dinitrotoluene		0.125	0.26	0.143	Z-stat	0.13	0.033	EDQL	7.88	4.33	3.94
2-Nitrotoluene		0.125	0.25	0.141	Z-stat	0.13					
3-Nitrotoluene		0.12	0.25	0.141	Z-stat	0.13					
4-Nitrotoluene		0.125	0.25	0.149	Z-stat	0.14					
HMX		0.125	1.2	0.655	Z-stat	0.52					

Table 5-1. Pad 37 and 38 General Screening Recalculation (continued)

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[e]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Nitrobenzene		0.054	0.26	0.141	Z-stat	0.13	1.31	EDQL	0.1984733	0.11	0.10
Nitrocellulose		2	315	315	Max selected	164.67					
Nitroglycerin		1.25	12	3.49	Z-stat	2.25					
Nitroguanidine		0.125	0.25	0.28	Z-stat	0.21					
RDX		0.25	6.5	1.37	Z-stat	0.85	5.8	Shrew	1.1206897	0.24	0.15

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 37 and 38.
[d]The general screening value is based on the Oak Ridge National Laboratory screening values (inorganics) or Region 5 EDQLs (explosives; RDX is based on the U.S. Environmental Protection Agency Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
EDQL = Ecological Data Quality Level.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RVAAP = Ravenna Army Ammunition Plant.
UCL = upper control limit.

Table 5-2. Pad 37 and 38 Plant HQ Rescreen

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Plant Screening Value[c]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0.23	2.8	0.682	Z-stat	0.46				
Aluminum	9750	30700	17941.17	Z-stat	16413.64	50	614	358.82	328.27
Antimony	0.15	6.1	1.81	Land's	1.35	5	1.22	0.36	0.27
Arsenic	0.31	25.6	13.39	t-stat	11.52	10	2.56	1.34	1.15
Barium	54.8	596	193.44	Z-stat	154.72	500	1.19	0.39	0.31
Beryllium	0.17	10.9	2.18	Z-stat	1.43	10	1.09	0.22	0.14
Cadmium	0.073	877	71.2	Land's	34.24	4	219.25	17.80	8.56
Calcium	637	247000	121863.25	Land's	35738				
Chromium	3.4	37.6	21.45	t-stat	19.5	1	37.6	21.45	19.50
Cobalt	0.92	11.5	8.41	t-stat	7.68	20	0.575	0.42	0.38
Copper	0.32	491	67.99	Z-stat	39.93	100	4.91	0.68	0.40
Iron	1350	31800	24539.89	Z-stat	22115				
Lead	0.15	1490	216.95	Z-stat	137.01	50	29.8	4.34	2.74
Magnesium	1520	53700	12134.635	Z-stat	8148.93				
Manganese	278	4270	1258.65	Land's	1017.36	500	8.54	2.52	2.03
Mercury	0.015	0.941	0.108	Z-stat	0.06	0.3	3.14	0.36	0.20
Nickel	4	23.9	17.44	t-stat	15.79	30	0.80	0.58	0.53
Potassium	606	3710	1742.63	Land's	1519.36				
Selenium	0.29	5	1.45	Land's	1.16	1	5	1.45	1.16
Silver	0.1	1.5	0.657	Z-stat	0.58	2	0.75	0.33	0.29
Sodium	23.7	2320	735.46	Land's	385.73				
Thallium	0.061	2.7	0.66	Z-stat	0.52	1	2.7	0.66	0.52
Vanadium	4.9	31	24.1	t-stat	22.16	2	15.5	12.05	11.08
Zinc	1	877	199.68	Z-stat	152.8	50	17.54	3.99	3.06
1,3,5-Trinitrobenzene	0.057	0.62	0.19	Z-stat	0.15				
1,3-Dinitrobenzene	0.088	0.25	0.14	Z-stat	0.13				
2,4,6-Trinitrotoluene	0.061	580	74.386	Z-stat	29.05				
2,4-Dinitrotoluene	0.063	0.31	0.202	Z-stat	0.18				
2,6-Dinitrotoluene	0.125	0.26	0.143	Z-stat	0.13				
2-Nitrotoluene	0.125	0.25	0.141	Z-stat	0.13				
3-Nitrotoluene	0.12	0.25	0.141	Z-stat	0.13				
4-Nitrotoluene	0.125	0.25	0.149	Z-stat	0.14				

Table 5-2. Pad 37 and 38 Plant HQ Rescreen (continued)

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Plant Screening Value[c]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
HMX	0.125	1.2	0.655	Z-stat	0.52				
Nitrobenzene	0.054	0.26	0.141	Z-stat	0.13				
Nitrocellulose	2	315	315	Max selected	164.67				
Nitroglycerin	1.25	12	3.49	Z-stat	2.25				
Nitroguanidine	0.125	0.25	0.28	Z-stat	0.21				
RDX	0.25	6.5	1.37	Z-stat	0.85				

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 37 and 38.
[d]The general screening value is based on Oak Ridge National Laboratory published screening values for plants.
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
UCL = upper control limit.

Table 5-3. Pad 37 and 38 Small Mammal HQ Rescreen

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Small Mammal - Shrew				Small Mammal - Mouse			
						Screening Value[d]	HQ of Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ of Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0.23	2.8	0.682	Z-stat	0.46								
Aluminum	9750	30700	17941.17	Z-stat	16413.64								
Antimony	0.15	6.1	1.81	Land's	1.35								
Arsenic	0.31	25.6	13.39	t-stat	11.52	9.9	2.59	1.35	1.16	149	0.17	0.09	0.08
Barium	54.8	596	193.44	Z-stat	154.72	329	1.81	0.59	0.47	1775	0.34	0.11	0.09
Beryllium	0.17	10.9	2.18	Z-stat	1.43								
Cadmium	0.073	877	71.2	Land's	34.24	6	146.17	11.87	5.71	63	13.92	1.13	0.54
Calcium	637	247000	121863.25	Land's	35738								
Chromium	3.4	37.6	21.45	t-stat	19.5	110	0.34	0.20	0.18	880	0.04	0.02	0.02
Cobalt	0.92	11.5	8.41	t-stat	7.68								
Copper	0.32	491	67.99	Z-stat	39.93	370	1.33	0.18	0.11	10100	0.05	0.01	0.00
Iron	1350	31800	24539.89	Z-stat	22115								
Lead	0.15	1490	216.95	Z-stat	137.01	740	2.01	0.29	0.19	6250	0.24	0.03	0.02
Magnesium	1520	53700	12134.635	Z-stat	8148.93								
Manganese	278	4270	1258.65	Land's	1017.36								
Mercury	0.015	0.941	0.108	Z-stat	0.06	0.146	6.45	0.74	0.41	7.1	0.13	0.02	0.01
Nickel	4	23.9	17.44	t-stat	15.79	246	0.10	0.07	0.06	1830	0.01	0.01	0.01
Potassium	606	3710	1742.63	Land's	1519.36								
Selenium	0.29	5	1.45	Land's	1.16								
Silver	0.1	1.5	0.657	Z-stat	0.58								
Sodium	23.7	2320	735.46	Land's	385.73								
Thallium	0.061	2.7	0.66	Z-stat	0.52	2.1	1.29	0.31	0.25	48.5	0.06	0.01	0.01
Vanadium	4.9	31	24.1	t-stat	22.16	55	0.56	0.44	0.40	1120	0.03	0.02	0.02
Zinc	1	877	199.68	Z-stat	152.8	1600	0.55	0.12	0.10	35000	0.03	0.01	0.00
1,3,5-Trinitrobenzene	0.057	0.62	0.19	Z-stat	0.15								
1,3-Dinitrobenzene	0.088	0.25	0.14	Z-stat	0.13								
2,4,6-Trinitrotoluene	0.061	580	74.386	Z-stat	29.05								
2,4-Dinitrotoluene	0.063	0.31	0.202	Z-stat	0.18								
2,6-Dinitrotoluene	0.125	0.26	0.143	Z-stat	0.13								
2-Nitrotoluene	0.125	0.25	0.141	Z-stat	0.13								
3-Nitrotoluene	0.12	0.25	0.141	Z-stat	0.13								
4-Nitrotoluene	0.125	0.25	0.149	Z-stat	0.14								
HMX	0.125	1.2	0.655	Z-stat	0.52								
Nitrobenzene	0.054	0.26	0.141	Z-stat	0.13								
Nitrocellulose	2	315	315	Max selected	164.67								
Nitroglycerin	1.25	12	3.49	Z-stat	2.25								

Table 5-3. Pad 37 and 38 Small Mammal HQ Rescreen (continued)

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Small Mammal - Shrew				Small Mammal - Mouse			
						Screening Value[d]	HQ of Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ of Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Nitroguanidine	0.125	0.25	0.28	Z-stat	0.21								
RDX	0.25	6.5	1.37	Z-stat	0.85	5.8	1.12	0.24	0.15				

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 37 and 38 (note nondetects were calculated at one-half reporting limit).
[d]The general screening value is based on Oak Ridge National Laboratory published ecological benchmarks (RDX is based on Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
UCL = upper control limit.

Table 5-4. Pad 58 and 59 General HQ Rescreen

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0	0.064	0.35	0.312	Z-stat	0.29					
Aluminum	17700	5920	20000	13703.04	Land's	12770.77	50	Plant	400	274.06	255.42
Antimony	0.96	0.6	157	16.69	Land's	11.39	5	Plant	31.4	3.34	2.28
Arsenic	15.4	5.7	33.5	14.36	Land's	13.16	9.9	Shrew/plant	3.38	1.45	1.33
Barium	88.4	38.3	629	144.34	Land's	122.76	283	Woodcock	2.22	0.51	0.43
Beryllium	0.88	0.1	0.81	0.52	Land's	0.44	10	Plant	0.08	0.05	0.04
Cadmium	0	0.11	80	4.66	Land's	3.79	4	Plant	20	1.17	0.95
Calcium	15800	506	28600	1018.19	Land's	6033.08					
Chromium	17.4	8.8	189	37.41	Z-stat	28.97	0.4	Earthworm	472.5	93.53	72.43
Cobalt	10.4	6.5	21.7	10.81	Land's	10.09	20	Plant	1.085	0.54	0.50
Copper	17.7	9.6	653	191.81	Land's	119.44	60	Earthworm	10.88	3.20	1.99
Iron	23100	13400	57100	28669.61	Z-stat	26550					
Lead	26.1	6.4	2800	533.48	Land's	277.05	40.5	Woodcock	69.14	13.17	6.84
Magnesium	3030	1700	7280	3638.27	Land's	3245.83					
Manganese	1450	177	1630	533.28	Land's	471.23					
Mercury	0.04	0.02	1.4	0.25	Land's	0.19	0.00051	Woodcock	2745.10	490.20	372.55
Nickel	21.1	12.6	50.7	27.17	Land's	24.59	30	Plant	1.69	0.91	0.82
Potassium	927	556	2950	1739.28	Land's	1514.47					
Selenium	1.4	0.17	2.4	1.12	Z-stat	0.96	0.21	Mouse	11.43	5.33	4.57
Silver	0	0.22	22.5	3.21	Z-stat	2.17	2	Plant	11.25	1.61	1.09
Sodium	123	28	638	356.55	Z-stat	290.84					
Thallium	0	0.3	0.8	0.55	T-Stat	0.51	1	Plant	0.8	0.55	0.51
Vanadium	31.1	8.8	35.6	23.58	T-Stat	22.17	2	Plant	17.8	11.79	11.09
Zinc	61.8	31.5	4520	699.98	Z-stat	470.96	8.5	Woodcock	531.76	82.35	55.41
1,3,5-Trinitrobenzene		0.125	0.125	0.125	ND	0.125	0.376		0.33	0.33	0.33
1,3-Dinitrobenzene		0.125	0.125	0.125	ND	0.125	0.655		0.19	0.19	0.19
2,4,6-Trinitrotoluene		0.125	33	5.242	Z-stat	2.06	140		0.24	0.04	0.01
2,4-Dinitrotoluene		0.125	0.125	0.125	ND	0.125	1.28		0.10	0.10	0.10
2,6-Dinitrotoluene		0.125	0.13	0.127	t-stat	0.13	0.033		3.94	3.85	3.94
2-Nitrotoluene		0.125	0.125	0.125	ND	0.125					
3-Nitrotoluene		0.125	0.125	0.125	ND	0.125					
4-Nitrotoluene		0.125	0.125	0.125	ND	0.125					
HMX		0.12	1	0.494	Z-stat	0.37					

Table 5-4. Pad 58 and 59 General HQ Rescreen (continued)

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Nitrobenzene		0.125	0.13	0.127	Z-stat	0.13	1.31		0.0992366	0.10	0.10
Nitrocellulose		2	2	2	Only 2 run	2					
Nitroglycerin		1.25	1.25	1.25	ND	1.25					
Nitroguanidine		0.25	2.5	2.5	Only 2 run	1.38					
RDX		0.18	2.5	0.664	Z-stat	0.45	5.8	Shrew	0.4310345	0.11	0.08

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 58 and 59 (Note: Nondetects were averaged in as one-half the reporting limit).
[d]The general screening value is based on the Oak Ridge National Laboratory screening values (inorganics) or Region 5 EDQLs (explosives; RDX is based on the U.S. Environmental Protection Agency Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
EDQL = Ecological Data Quality Level.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RVAAP = Ravenna Army Ammunition Plant.
UCL = upper control limit.

Table 5-5. Pad 58 and 59 Plant HQ Rescreen

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Plant Screening Value[c]	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0.064	0.35	0.312	Z-stat	0.29			
Aluminum	5920	20000	13703.04	Land's	12770.77	50	274.06	255.42
Antimony	0.6	157	16.69	Land's	11.39	5	3.34	2.28
Arsenic	5.7	33.5	14.36	Land's	13.16	10	1.44	1.32
Barium	38.3	629	144.34	Land's	122.76	500	0.29	0.25
Beryllium	0.1	0.81	0.52	Land's	0.44	10	0.05	0.04
Cadmium	0.11	80	4.66	Land's	3.79	4	1.17	0.95
Calcium	506	28600	1018.19	Land's	6033.08			
Chromium	8.8	189	37.41	Z-stat	28.97	1	37.41	28.97
Cobalt	6.5	21.7	10.81	Land's	10.09	20	0.54	0.50
Copper	9.6	653	191.81	Land's	119.44	100	1.92	1.19
Iron	13400	57100	28669.61	Z-stat	26550			
Lead	6.4	2800	533.48	Land's	277.05	50	10.67	5.54
Magnesium	1700	7280	3638.27	Land's	3245.83			
Manganese	177	1630	533.28	Land's	471.23	500	1.07	0.94
Mercury	0.02	1.4	0.25	Land's	0.19	0.3	0.83	0.63
Nickel	12.6	50.7	27.17	Land's	24.59	30	0.91	0.82
Potassium	556	2950	1739.28	Land's	1514.47			
Selenium	0.17	2.4	1.12	Z-stat	0.96	1	1.12	0.96
Silver	0.22	22.5	3.21	Z-stat	2.17	2	1.61	1.09
Sodium	28	638	356.55	Z-stat	290.84			
Thallium	0.3	0.8	0.55	t-stat	0.51	1	0.55	0.51
Vanadium	8.8	35.6	23.58	t-stat	22.17	2	11.79	11.09
Zinc	31.5	4520	699.98	Z-stat	470.96	50	14.00	9.42
1,3,5-Trinitrobenzene	0.125	0.125	0.125	ND	0.125			
1,3-Dinitrobenzene	0.125	0.125	0.125	ND	0.125			
2,4,6-Trinitrotoluene	0.125	33	5.242	Z-stat	2.06			
2,4-Dinitrotoluene	0.125	0.125	0.125	ND	0.125			
2,6-Dinitrotoluene	0.125	0.13	0.127	t-stat	0.13			
2-Nitrotoluene	0.125	0.125	0.125	ND	0.125			
3-Nitrotoluene	0.125	0.125	0.125	ND	0.125			
4-Nitrotoluene	0.125	0.125	0.125	ND	0.125			

Table 5-5. Pad 58 and 59 Plant HQ Rescreen (continued)

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Plant Screening Value[c]	HQ on 95% UCL	HQ on Arithmetic Mean
HMX	0.12	1	0.494	Z-stat	0.37			
Nitrobenzene	0.125	0.13	0.127	Z-stat	0.13			
Nitrocellulose	2	2	2	Only 2 run	2			
Nitroglycerin	1.25	1.25	1.25	ND	1.25			
Nitroguanidine	0.25	2.5	2.5	Only 2 run	1.38			
RDX	0.18	2.5	0.664	Z-stat	0.45			

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data from pads 58 and 59 (Note: nondetects are averaged as one-half the reporting limit).
[d]The general screening value is based on the Oak Ridge National Laboratory published ecological benchmarks (RDX is based on Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
UCL = upper control limit.

Table 5-6. Pad 58 and 59 Small Mammal HQ Rescreen

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL Based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Small Mammal - Shrew				Small Mammal - Mouse			
						Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0.064	0.35	0.312	Z-stat	0.29								
Aluminum	5920	20000	13703.04	Land's	12770.77								
Antimony	0.6	157	16.69	Land's	11.39								
Arsenic	5.7	33.5	14.36	Land's	13.16	9.9	3.38	1.45	1.33	149	0.224832	0.10	0.09
Barium	38.3	629	144.34	Land's	122.76	329	1.91	0.44	0.37	1775	0.354366	0.08	0.07
Beryllium	0.1	0.81	0.52	Land's	0.44								
Cadmium	0.11	80	4.66	Land's	3.79	6	13.33	0.78	0.63	63	1.269841	0.07	0.06
Calcium	506	28600	1018.19	Land's	6033.08								
Chromium	8.8	189	37.41	Z-stat	28.97	110	1.72	0.34	0.26	880	0.214773	0.04	0.03
Cobalt	6.5	21.7	10.81	Land's	10.09								
Copper	9.6	653	191.81	Land's	119.44	370	1.76	0.52	0.32	10100	0.064653	0.02	0.01
Iron	13400	57100	28669.61	Z-stat	26550								
Lead	6.4	2800	533.48	Land's	277.05	740	3.78	0.72	0.37	6250	0.448	0.09	0.04
Magnesium	1700	7280	3638.27	Land's	3245.83								
Manganese	177	1630	533.28	Land's	471.23								
Mercury	0.02	1.4	0.25	Land's	0.19	0.146	9.59	1.71	1.30	7.1	0.197183	0.04	0.03
Nickel	12.6	50.7	27.17	Land's	24.59	246	0.21	0.11	0.10	1830	0.027705	0.01	0.01
Potassium	556	2950	1739.28	Land's	1514.47								
Selenium	0.17	2.4	1.12	Z-stat	0.96								
Silver	0.22	22.5	3.21	Z-stat	2.17								
Sodium	28	638	356.55	Z-stat	290.84								
Thallium	0.3	0.8	0.55	t-stat	0.51	2.1	0.38	0.26	0.24	48.5	0.016495	0.01	0.01
Vanadium	8.8	35.6	23.58	t-stat	22.17	55	0.65	0.43	0.40	1120	0.031786	0.02	0.02
Zinc	31.5	4520	699.98	Z-stat	470.96	1600	2.83	0.44	0.29	35000	0.129143	0.02	0.01
1,3,5-Trinitrobenzene	0.125	0.125	0.125	ND	0.125								
1,3-Dinitrobenzene	0.125	0.125	0.125	ND	0.125								
2,4,6-Trinitrotoluene	0.125	33	5.242	Z-stat	2.06								
2,4-Dinitrotoluene	0.125	0.125	0.125	ND	0.125								
2,6-Dinitrotoluene	0.125	0.13	0.127	t-stat	0.13								
2-Nitrotoluene	0.125	0.125	0.125	ND	0.125								
3-Nitrotoluene	0.125	0.125	0.125	ND	0.125								
4-Nitrotoluene	0.125	0.125	0.125	ND	0.125								
HMX	0.12	1	0.494	Z-stat	0.37								
Nitrobenzene	0.125	0.13	0.127	Z-stat	0.13								
Nitrocellulose	2	2	2	Only 2 run	2								
Nitroglycerin	1.25	1.25	1.25	ND	1.25								

Table 5-6. Pad 58 and 59 Small Mammal HQ Rescreen (continued)

Analyte	Minimum Concentration	Maximum Concentration	95% UCL or Maximum[a]	UCL Based on Z-stat, Land's, or t-stat	Arithmetic Mean Concentration	Small Mammal - Shrew				Small Mammal - Mouse			
						Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Nitroguanidine	0.25	2.5	2.5	Only 2 run	1.38								
RDX	0.18	2.5	0.664	Z-stat	0.45	5.8	0.43	0.11	0.08				

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 58 and 59 (Note: nondetects are averaged as one-half the reporting limit).
[d]The general screening value is based on Oak Ridge National Laboratory published ecological benchmarks (RDX is based on Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
UCL = upper control limit.

Table 5-7. Pad 66 and 67 General HQ Rescreen

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[e]	HQ on Maximum	HQ on 95% UCL or Max.	HQ on Arithmetic Mean
Cyanide	0	0.29	1.8	0.78	Z-stat	0.63					
Aluminum	17700	6330	18100	13461.77	t-stat	12721.71	50	Plant	362	269.24	254.43
Antimony	0.96	0.61	45.1	7.8	Z-stat	5.24	5	Plant	9.02	1.56	1.05
Arsenic	15.4	8.4	17.9	13.17	Land's	12.43	9.9	Shrew/plant	1.81	1.33	1.26
Barium	88.4	69.8	7780	2195.58	Land's	1292.99	283	Woodcock	27.49	7.76	4.57
Beryllium	0.88	0.13	0.69	0.44	Land's	0.38	10	Plant	0.07	0.04	0.04
Cadmium	0	0.025	15.7	4.78	Land's	2.05	4	Plant	3.93	1.20	0.51
Calcium	15800	713	46600	8556.67	Land's	5847.4					
Chromium	17.4	7	195	31.18	Z-stat	22.76	0.4	Earthworm	487.5	77.95	56.90
Cobalt	10.4	1.6	18.2	8.69	Z-stat	7.84	20	Plant	0.91	0.43	0.39
Copper	17.7	16.5	1920	317.58	Z-stat	200.5	60	Earthworm	32	5.29	3.34
Iron	23100	14700	32200	25537.63	Land's	23996.67					
Lead	26.1	14.5	1010	155.07	Z-stat	105.65	40.5	Woodcock	24.94	3.83	2.61
Magnesium	3030	1480	3970	2902.16	Land's	2693					
Manganese	1450	165	2020	835.91	Land's	703.23					
Mercury	0.04	0.02	0.53	0.16	Land's	0.12	0.00051	Woodcock	1039.22	313.73	235.29
Nickel	21.1	11.2	33.1	17.73	Z-stat	16.54	30	Plant	1.10	0.59	0.55
Potassium	927	538	1980	1426.51	t-stat	1323.7					
Selenium	1.4	0.05	1.8	1.02	Z-stat	0.88	0.21	Mouse	8.57	4.86	4.19
Silver	0	0.11	1.8	0.65	Z-stat	0.57	2	Plant	0.9	0.33	0.29
Sodium	123	43.5	646	172.59	Land's	138.02					
Thallium	0	0.29	0.71	0.5	Land's	0.46	1	Plant	0.71	0.50	0.46
Vanadium	31.1	13.7	33.1	25.08	Land's	23.29	2	Plant	16.55	12.54	11.65
Zinc	61.8	36.2	1590	401.14	Land's	296.58	8.5	Woodcock	187.06	47.19	34.89
1,3,5-Trinitrobenzene		0.12	76	26.74	Z-stat	18.59	0.376		202.13	71.12	49.44
1,3-Dinitrobenzene		0.042	31	6	Z-stat	3.06	0.655		47.33	9.16	4.67
2,4,6-Trinitrotoluene		0.28	3800	1167.1	Z-stat	729	140		27.14	8.34	5.21
2,4-Dinitrotoluene		0.085	12.5	1.934	Z-stat	0.87	1.28		9.77	1.51	0.68
2,6-Dinitrotoluene		0.087	37.5	11.26	Z-stat	6.76	0.033		1136.36	341.21	204.85
2-Nitrotoluene		0.125	31	5.56	Z-stat	2.73					
3-Nitrotoluene		0.125	21	4.29	Z-stat	2.22					
4-Nitrotoluene		0.125	31	5.56	Z-stat	2.73					
HMX		0.25	1700	301.18	Z-stat	155.63					

Table 5-7. Pad 66 and 67 General HQ Rescreen (continued)

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithimetic Mean Concentration[c] (mg/kg)	General Screening Value[d] (mg/kg)	General Screen Endpoint[e]	HQ on Maximum	HQ on 95% UCL or Max.	HQ on Arthimetic Mean
Nitrobenzene		0.035	31	5.57	Z-stat	2.73	1.31		23.66	4.25	2.08
Nitrocellulose		2	32.2	32.2	Max used	10.65					
Nitroglycerin		1.25	10.5	5.17	Z-stat	3.84					
Nitroguanidine		0.125	0.25	0.27	Z-stat	0.22					
RDX		0.18	9500	1701.86	Z-stat	877.48	5.8	Shrew	1637.93	293.42	151.29

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 58 and 59 (Note: nondetects are averaged as one-half the reporting limit).
[d]The general screening value is based on Oak Ridge National Laboratory published ecological benchmarks (RDX is based on Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RVAAP = Ravenna Army Ammunition Plant.
UCL = upper control limit.

Table 5-8. Pad 66 and 67 Plant HQ Rescreen

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	Plant Screening Value[c]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0	0.29	1.8	0.78	Z-stat	0.63				
Aluminum	17700	6330	18100	13461.77	t-stat	12721.71	50	362	269.24	254.43
Antimony	0.96	0.61	45.1	7.8	Z-stat	5.24	5	9.02	1.56	1.05
Arsenic	15.4	8.4	17.9	13.17	Land's	12.43	10	1.79	1.32	1.24
Barium	88.4	69.8	7780	2195.58	Land's	1292.99	500	15.56	4.39	2.59
Beryllium	0.88	0.13	0.69	0.44	Land's	0.38	10	0.069	0.04	0.04
Cadmium	0	0.025	15.7	4.78	Land's	2.05	4	3.925	1.20	0.51
Calcium	15800	713	46600	8556.67	Land's	5847.4				
Chromium	17.4	7	195	31.18	Z-stat	22.76	1	195	31.18	22.76
Cobalt	10.4	1.6	18.2	8.69	Z-stat	7.84	20	0.91	0.43	0.39
Copper	17.7	16.5	1920	317.58	Z-stat	200.5	100	19.2	3.18	2.01
Iron	23100	14700	32200	25537.63	Land's	23996.67				
Lead	26.1	14.5	1010	155.07	Z-stat	105.65	50	20.2	3.10	2.11
Magnesium	3030	1480	3970	2902.16	Land's	2693				
Manganese	1450	165	2020	835.91	Land's	703.23	500	4.04	1.67	1.41
Mercury	0.04	0.02	0.53	0.16	Land's	0.12	0.3	1.766667	0.53	0.40
Nickel	21.1	11.2	33.1	17.73	Z-stat	16.54	30	1.103333	0.59	0.55
Potassium	927	538	1980	1426.51	t-stat	1323.7				
Selenium	1.4	0.05	1.8	1.02	Z-stat	0.88	1	1.8	1.02	0.88
Silver	0	0.11	1.8	0.65	Z-stat	0.57	2	0.9	0.33	0.29
Sodium	123	43.5	646	172.59	Land's	138.02				
Thallium	0	0.29	0.71	0.5	Land's	0.46	1	0.71	0.50	0.46
Vanadium	31.1	13.7	33.1	25.08	Land's	23.29	2	16.55	12.54	11.65
Zinc	61.8	36.2	1590	401.14	Land's	296.58	50	31.8	8.02	5.93
1,3,5-Trinitrobenzene		0.12	76	26.74	Z-stat	18.59				
1,3-Dinitrobenzene		0.042	31	6	Z-stat	3.06				
2,4,6-Trinitrotoluene		0.28	3800	1167.1	Z-stat	729				
2,4-Dinitrotoluene		0.085	12.5	1.934	Z-stat	0.87				
2,6-Dinitrotoluene		0.087	37.5	11.26	Z-stat	6.76				
2-Nitrotoluene		0.125	31	5.56	Z-stat	2.73				
3-Nitrotoluene		0.125	21	4.29	Z-stat	2.22				
4-Nitrotoluene		0.125	31	5.56	Z-stat	2.73				

Table 5-8. Pad 66 and 67 Plant HQ Rescreen (continued)

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	Plant Screening Value[c]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
HMX		0.25	1700	301.18	Z-stat	155.63				
Nitrobenzene		0.035	31	5.57	Z-stat	2.73				
Nitrocellulose		2	32.2	32.2	Max used	10.65				
Nitroglycerin		1.25	10.5	5.17	Z-stat	3.84				
Nitroguanidine		0.125	0.25	0.27	Z-stat	0.22				
RDX		0.18	9500	1701.86	Z-stat	877.48				

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 58 and 59 (Note: nondetects are averaged as one-half the reporting limit).
[d]The general screening value is based on Oak Ridge National Laboratory published ecological benchmarks (RDX is based onEcological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RVAAP = Ravenna Army Ammunition Plant.
UCL = upper control limit.

Table 5-9. Pad 66 and 67 Small Mammal Rescreen

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	Small Mammal - Shrew				Small Mammal - Mouse			
							Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Cyanide	0	0.29	1.8	0.78	Z-stat	0.63								
Aluminum	17700	6330	18100	13461.77	t-stat	12721.71								
Antimony	0.96	0.61	45.1	7.8	Z-stat	5.24								
Arsenic	15.4	8.4	17.9	13.17	Land's	12.43	9.9	1.81	1.33	1.26	149	0.12	0.09	0.08
Barium	88.4	69.8	7780	2195.58	Land's	1292.99	329	23.65	6.67	3.93	1775	4.38	1.24	0.73
Beryllium	0.88	0.13	0.69	0.44	Land's	0.38								
Cadmium	0	0.025	15.7	4.78	Land's	2.05	6	2.62	0.80	0.34	63	0.25	0.08	0.03
Calcium	15800	713	46600	8556.67	Land's	5847.4								
Chromium	17.4	7	195	31.18	Z-stat	22.76	110	1.77	0.28	0.21	880	0.22	0.04	0.03
Cobalt	10.4	1.6	18.2	8.69	Z-stat	7.84								
Copper	17.7	16.5	1920	317.58	Z-stat	200.5	370	5.19	0.86	0.54	10100	0.19	0.03	0.02
Iron	23100	14700	32200	25537.63	Land's	23996.67								
Lead	26.1	14.5	1010	155.07	Z-stat	105.65	740	1.36	0.21	0.14	6250	0.16	0.02	0.02
Magnesium	3030	1480	3970	2902.16	Land's	2693								
Manganese	1450	165	2020	835.91	Land's	703.23								
Mercury	0.04	0.02	0.53	0.16	Land's	0.12	0.146	3.63	1.10	0.82	7.1	0.07	0.02	0.02
Nickel	21.1	11.2	33.1	17.73	Z-stat	16.54	246	0.13	0.07	0.07	1830	0.02	0.01	0.01
Potassium	927	538	1980	1426.51	t-stat	1323.7								
Selenium	1.4	0.05	1.8	1.02	Z-stat	0.88								
Silver	0	0.11	1.8	0.65	Z-stat	0.57								
Sodium	123	43.5	646	172.59	Land's	138.02								
Thallium	0	0.29	0.71	0.5	Land's	0.46	2.1	0.34	0.24	0.22	48.5	0.01	0.01	0.01
Vanadium	31.1	13.7	33.1	25.08	Land's	23.29	55	0.60	0.46	0.42	1120	0.03	0.02	0.02
Zinc	61.8	36.2	1590	401.14	Land's	296.58	1600	0.99	0.25	0.19	35000	0.05	0.01	0.01
1,3,5-Trinitrobenzene		0.12	76	26.74	Z-stat	18.59								
1,3-Dinitrobenzene		0.042	31	6	Z-stat	3.06								
2,4,6-Trinitrotoluene		0.28	3800	1167.1	Z-stat	729								
2,4-Dinitrotoluene		0.085	12.5	1.934	Z-stat	0.87								
2,6-Dinitrotoluene		0.087	37.5	11.26	Z-stat	6.76								
2-Nitrotoluene		0.125	31	5.56	Z-stat	2.73								
3-Nitrotoluene		0.125	21	4.29	Z-stat	2.22								
4-Nitrotoluene		0.125	31	5.56	Z-stat	2.73								
HMX		0.25	1700	301.18	Z-stat	155.63								
Nitrobenzene		0.035	31	5.57	Z-stat	2.73								
Nitrocellulose		2	32.2	32.2	Max used	10.65								
Nitroglycerin		1.25	10.5	5.17	Z-stat	3.84								

Table 5-9. Pad 66 and 67 Small Mammal Rescreen (continued)

Analyte	RVAAP Background (mg/kg)	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% UCL or Maximum[a] (mg/kg)	UCL Basis[b]	Arithmetic Mean Concentration[c] (mg/kg)	Small Mammal - Shrew				Small Mammal - Mouse			
							Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean	Screening Value[d]	HQ on Maximum	HQ on 95% UCL	HQ on Arithmetic Mean
Nitroguanidine		0.125	0.25	0.27	Z-stat	0.22								
RDX		0.18	9500	1701.86	Z-stat	877.48	5.8	1637.93	293.42	151.29				

[a]95% UCL is listed unless it is greater than the maximum concentration detected at the site. If max is selected, it is noted in the UCL basis column.
[b]The UCL was calculated using the Z-stat, t-stat, or Land's method depending on which best fit the data set. Selection was made by the statistical program.
[c]The arithmetic mean of all data for pads 58 and 59 (Note: nondetects are averaged as one-half the reporting limit).
[d]The general screening value is based on Oak Ridge National Laboratory published ecological benchmarks (RDX is based on Ecological Soil Screening Levels).
[e]The endpoint that the general screening value is based upon.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
HQ = hazard quotient.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RVAAP = Ravenna Army Ammunition Plant.
UCL = upper control limit.

6.0 VEGETATION

6.1 RATIONALE AND BACKGROUND

Vegetation constitutes a fundamental component of all ecological resources, the source of most food. Vegetation greatly influences habitat for wildlife and prevents or reduces erosion. Vegetation is widely distributed at the WBG and was selected as an objective of study in the current field investigation. The purposes, statistical methods, and locations for this investigation are explained in Chapters 1.0 (Introduction), 2.0 (Scope and Objectives), 3.0 (Statistical Design), and 4.0 (Study Sites).

The study team chose the burning pad as the unit of study. The actual dimensions of the areas cleared and leveled for burning varied from site to site, but they were roughly rectangular areas that ranged from approximately 30.5 by 30.5 m (100 by 100 ft) to 15 by 20 m (49 by 66 ft) for the pads selected for study. A 15- by 20-m (49- by 66-ft) rectangular sampling grid of 300 m^2 was chosen to identify the sampling locations at each pad. This size was chosen so that it would completely cover the smaller pads (pads 59, 66, and 67).

The vegetation sampling grid was placed within the burning pad area. Plots were chosen at random from within the vegetation sampling grid to obtain samples that were representative of the entire grid and also the pad. While individual plots sampled may have had high or low contamination or high or low values of the vegetation metrics, together these samples represent the condition over the entire pad site. The Wilcoxon rank sum test was used to compare the WBG with the reference sites tests, and this applies to the entire pad because the samples taken are representative of the entire pad.

Initially, information about 15 methods for measuring various attributes of plants was gathered and organized into five types of measurements: vegetation community measures, vegetation diversity measures, vegetation biomarkers, chemical analyses of plant tissues, and plant toxicity tests. Four selection criteria were applied to each of the 15 methods. These criteria were ecological significance of method, amount of work involved, where the method works best, and variability of the method (Table 6-1). The greater the ecological relevance, lesser the amount of work, clearer the application to WBG, and lesser the variability combined to recognize the following best of the 15 methods: plant community percent cover, plant community composition, symbiont measures, and terrestrial plant toxicity tests (SAIC 1999b). During development of the SAP (SAIC 2000), these methods were further discussed and the following vegetation metrics were selected for the field-truthing effort: percent cover, species richness, stem density, biomass, and community composition.

The following section describes the methods used for sampling and evaluating the vegetation at contaminated burning pad sites at the WBG and the reference sites outside the WBG. Analytical and statistical methods used to characterize collocated soil samples are explained in Chapter 4.0.

6.2 SAMPLING METHODS

6.2.1 Vegetation Metrics

Vegetation metrics (Table 6-2) were measured or calculated from a minimum of 30 plots: 27 plots randomly selected, using a random number generator, plus 3 selected cover sample plots at each of the 3 pairs of burning pads and 30 plots at each of their respective 3 pairs of reference sites, for a total of 180 samples. See Chapter 3.0 and Table 3-1 for the explanation of why a minimum 54 samples were required from each set

of burning pad sites and reference sites. See Appendix A (SAIC 2001) for representative photographs of the appearance of burning pad sites and reference sites.

There were circumstances where the number of samples differed from the typical 30 per pair of burning pad sites and 30 per pair of reference sites. Plots for vegetation sampling were selected randomly. Within each set of 30 (if possible), plots were selected on a biased basis as follows. Plots were selected to represent a range of vegetative cover ("selected-cover" plots). Three of these were located in each of the three following areas: (1) bare-to-sparse cover (0 to 29); (2) scattered medium cover (30 to 69); and (3) high cover (70 to 100) [Figure 4-2]. The randomly selected samples from each pair of sample sites, from which the 9 stratified selected-cover samples were selected, were, on occasion, insufficient to contain an adequate number of bare-to-sparse (0 to 29) and scattered medium (30 to 69)-cover plots. In those instances, sparse and medium selected-cover plots were identified and selected by visual inspection of neighboring plots. Up to three of the original 30 were replaced by the visually identified bare-to-sparse or medium-cover plots. If more than three plots were located outside of the randomly chosen plots, the additional plots were added to, rather than substituted for, those plots randomly chosen to meet statistical assumptions. For this reason, there were more than 30 samples per pair of burning pads. Table 6-3 shows the total number of samples and which ones were random and which were nonrandom (when vegetation cover requirements dictated).

Following the layout of grids, the sample area, and random selection of the sample plots, a photograph of each plot to be sampled was taken by a member of the field team. Each photograph was taken from the fifth rung of a stepladder, approximately 1.5 to 2 m (~5 to 6.5 ft) above the plot. The photographs and accompanying photo log provide a permanent record of each sample plot. Photographs were listed by roll number and frame number in the field manager's logbook, and the log includes date taken, pad number and sample plot number (location), and the name of the photographer. Representative examples of these photographs are included in SAIC 2001.

6.2.1.1 Percent cover

The 1-m^2 plots were first evaluated for percent cover. Objective measurements of cover were made using a cover pin frame. A frame the length of one side of the plot, with double rows of 10 pins spaced at 10-cm intervals, was laid over the sample area and lowered vertically until the pins reach the ground. The number of pins not touching vegetation was recorded. The procedure was repeated 5 times as the frame was moved at 20-cm (8-in.) intervals along the side of the plot. The percentage of pins that did not touch vegetation became a measure of the percentage of area not covered by vegetation. Subtraction from 100 gives the percent cover. For example, if a total of 30 pins did not touch vegetation during the 5 measurements, the percent cover would be 70.

6.2.1.2 Species richness

The second sample metric was identifying all plant species in each 1-m^2 plot to determine species richness (number of different plant species present). This was the second measurement taken at all plots. Plants present in each plot were identified to species and recorded in the log book. If species-level identification was not possible due to immature stage or lack of flowers or fruits, unknowns were identified to the genus or family level using dichotomous botanical keys. Appendix B (SAIC 2001) contains species and stem counts for vegetation.

6.2.2 Stem Density

Following the percent cover and species richness measurements, each randomly selected 1-m^2 plot was divided into quarters (0.25 m^2 each) (Figure 4-1). One of these quarters was randomly selected for the

vegetation sampling for stem density (number of stems present) and biomass (dry weight of the aboveground plant material). The number of stems of each species present was also recorded to allow calculation of the Shannon Diversity Index. The number of individuals (stems) of each species present within the 0.25-m^2 plot was recorded on the data sheet for each plot (SAIC 2001).

6.2.2.1 Biomass

Assessment of biomass (see Appendix A, SAIC 2001) was the last field measurement made on all plots (Figures 6-1 and 6-2). As stem density measurements were taken, the same 0.25-m^2 plot was harvested for biomass measurement. All stems within the quarter area were clipped at ground level, placed into large brown paper bags that had been weighed previously, and stapled twice at the top of each bag to keep all vegetation securely in the bag. Bags were labeled with pad or reference ID, plot number, and harvest date using waterproof-marking pens. The harvested and bagged material was placed in drying ovens as soon as possible after harvest (usually the same day) or hung on a line to air dry until space was available in the ovens. Plants were dried in a 70 to 80^{o}C oven until periodic weighing confirmed that weight loss had ceased, typically about 72 hours. Dry weights of plant material were obtained to the nearest 0.1 g immediately after removal from the drying oven, or biomass was redried before weighing. Bag weights were subtracted from the total dry weight to arrive at the net dry weight of biomass in each bag. Bags were weighed with and without staples. There was no measurable difference in the bag weights whether staples were included or not.

6.2.2.2 Community composition

The community composition metric was calculated for the burning pad sites and reference sites. The Shannon Diversity Index (Table 6-2) quantifies the relative abundance of all the species (the evenness of the species) and the number of species (species richness) most commonly used to express diversity. Diversity is considered an indicator of healthy plant communities. The Shannon Diversity Index was calculated from the stem density data. The higher the value of the Shannon Diversity Index, the more evenly abundance is spread among the species present (i.e., no few species dominate) for a constant number of species or the more species are present for a given evenness.

One aspect of community composition is exotic species. Native vegetation can include introduced plant species that are invasive. These plants are called exotics because they are introduced into a region by humans either deliberately or accidentally. While not all exotics are invasive, those that naturalize may become prolific reproducers and rampantly spread throughout natural areas. Because they lack the natural controls that keep them in check in their native range, invasive exotics outcompete and displace native vegetation. This effect can drastically change the composition of native plant communities and degrades the biodiversity of native habitats (Tennessee Exotic Pest Plant Council 1996). To assess the relative importance of native and exotic species in the burning pads and reference sites, the percentage of exotic species in each plot was calculated (the number of stems of exotic species multiplied by 100, divided by the total number of stems per square meter).

6.3 STATISTICAL PROCEDURES

See Chapter 3.0 on “Statistical Design” for the framework.

The distribution of each vegetation parameter for each site (e.g., pad pair 37 and 38) was tested using the Shapiro-Wilk test. The distributions were significantly different from normal ($p < 0.05$) for percent cover for all sites. For species richness, stem density, and biomass, the distributions were determined as being normal or not normal. The percent of exotic species had distributions different from normal while the

diversity index tended to be normally distributed. The Wilcoxon rank sum test was used to compare the distributions of each parameter between the paired contaminated and reference sites (Tables 6-4 and 6-5). The Wilcoxon rank sum test is appropriate for normal or non-normal distributions.

6.3.1 Comparisons of Vegetation Measures Between Reference and Contaminated Sites

Based on conceptual modeling (SAIC 2000), the contaminated sites would be expected to have lower values for percent cover, species richness, stem density, and biomass. The contaminated sites would also be expected to have a higher proportion of exotic species and a lower diversity index than the reference sites. It is possible, however, that contaminants could stimulate plant growth. Although there were definite expectations for the direction of the difference, the probabilities reported for the Wilcoxon rank sum test in Tables 6-4 and 6-5 are for a two-tailed test, to test for a difference in either direction. The probability for a one-tailed test would be one-half the probability reported in the tables.

For comparisons that did not demonstrate significant differences, the power of the tests is important. For the vegetation parameters, the power was estimated using the same equation that was used to calculate the number of samples needed. Rearranging Eq. D-3 from the SAP (SAIC 2000) results in:

$$\text{Power} = \Phi(Z_{1-\beta}) = \Phi\left[\sqrt{N3(\Phi(0.707\Delta/CV)-0.5)^2} - Z_{1-\alpha}\right],$$

where

Φ = the standard normal probability function,
$Z_{1-\alpha}$ = the value of the standard normal distribution that cuts off the upper α proportion of the distribution,
N = total number of measurements,
Δ/CV = the percent significant difference divided by the coefficient of variation,
$Z_{1-\beta}$ = the value of the standard normal distribution that cuts off the upper β proportion of the distribution.

Power is the probability that a difference of a certain size would be detected if the populations were really that different, given the observed variability and a specified alpha level. To simplify the calculation, the power is estimated assuming a normal distribution and equal sample sizes for the contaminated sites and reference sites.

The power target for these tests was 95. Another way to assess the power of the test is to estimate how large a difference could be detected with 95% confidence. The equation above was rearranged to solve for percent significant difference. Table 6-6 lists the estimated difference that could be detected with 95% power at a 5 alpha level.

6.3.2 Assessment of Species Composition

Plant stems were identified to the lowest taxonomic level that was readily identifiable when they were counted. This information allowed for the calculation of the species diversity index and percent exotic species. The percent of exotic species and species diversity index were compared between the contaminated sites and reference sites using the Wilcoxon rank sum test in the same manner as the vegetation abundance parameters were compared (Table 6-5).

The stem counts of individual species also allow for the comparison of the abundance of individual species between the contaminated sites and reference sites. There were a total of 109 species identified

over the 171 plots examined. The counts for each plot are presented in SAIC 2001. Rather than describe the distribution of each species, many of which were seldom observed, we chose to examine the distribution of those species that comprise at least one percent of the total number of stems counted. The 19 species with at least 1% abundance make up over 90% of the total number of stems counted (Table 6-7). About half (11) of these 19 species were considered exotic.

The stem counts for the 19 most abundant species were compared between the paired contaminated sites and reference sites using the Wilcoxon rank sum test like the other vegetation metrics (Table 6-8). Results are presented in Table 6-7 by species in order of percent stem abundance.

6.4 WEIGHT-OF-EVIDENCE APPROACH

Weight-of-evidence is used to compare WBG site findings with reference site findings. A weight-of-evidence approach evaluates multiple lines of evidence. This method identifies probable causes of observed ecological responses, using arguments derived from human epidemiology. In this approach, a causal relationship between a stressor and a response is proposed. Then a series of questions, or criteria, is applied to the proposition. Not all criteria need be satisfied to demonstrate that the proposition is likely true, but weight is added to the conclusion by each criterion that is satisfied in the proposition(s). Ultimately, professional judgment is used to establish the strength of the causal relationship. The weight-of-evidence approach is especially useful when: (1) there are insufficient data for robust statistical analyses, (2) toxicity or other criteria are uncertain, or (3) exposure models are not sufficiently precise for statistical hypothesis testing.

The criteria in the weight-of-evidence approach are as follows:

- Temporal association—did the supposed causes precede measurable effects?
- Spatial association—is the affected population exposed to the proposed causative agent?
- Stressor response—does the severity of the effect vary in response to the magnitude of exposure to the proposed causative agent?
- Strength of association—are there other potential causes that could be present or act antagonistically/synergistically to produce the observed effect?
- Plausibility—does the proposition make sense, and is it consistent with known etiological and scientific principles? Is there a reasonable mechanism of action?

Each of these criteria is further explained below.

Temporal associations rely on measures of biological populations or physical media being made before and after an event. If measurements were not made before the proposed cause, as is often the case, there may be no direct evidence for temporal association. Correlated fluctuations in the proposed stressors and the effect can provide evidence for both temporal association and quantitative stressor response.

Spatial association may be demonstrated by a decrease in the severity of effect in the indicator organisms with distance from the proposed causative agent. It may also be shown by a distribution of effects in relation to contaminant transport, such as location in the surface soil of a hot spot, in a groundwater plume, or downwind from an airborne source. Chemical transport models may describe the spatial

association in quantitative or qualitative terms. Spatial association can also be demonstrated through comparisons of stressed situations relative to an unstressed reference situation.

A positive correlation between the magnitudes of the stress and the response is strong evidence for causality. If a contaminant can be measured in the exposure media, then it can be quantitatively compared to the severity of observable or measurable effects. Ecological effects measurements are useful in establishing the stressor/response relationships. Otherwise, indirect measures of the effect may be made, including expected attenuation with distance from the proposed source.

Demonstrating strength of association requires an adequate database and application of good scientific judgment. Confounding factors must be taken into account when evaluating the strength of association. For example, several contaminants may be released into exposure media, and a population may respond simultaneously to more than one of them. The presence of an antagonist may mask the effects of a stressor, weakening the apparent temporal associations between stressor and effect.

Scenarios by which the stressor causes the observed response must be plausible. Scientifically sound principles, preferably backed by experimental evidence or other field observations, must be used in evaluating the plausibility of the proposition.

The lines of evidence are evaluated quantitatively or qualitatively depending on the types and quality of data available. For example, a gradient of effects in indicator organisms associated with distance from the proposed source may be used as evidence for spatial association. Evaluation of a temporal association may be based on circumstantial evidence rather than on data obtained directly before and after the event. Experimental evidence may also be used to evaluate these and other weight-of-evidence criteria. But, the practical sense of the weight-of-evidence approach consists of lists of pro and con observations based on the above themes. The evidence supporting or opposing the causal agents are presented after the results section.

6.5 RESULTS

Each vegetation metric is discussed separately in the sections below. The measurements for each plot are listed in Appendices A and B (SAIC 2001). Abundance measures are summarized in Table 6-4. Species composition measures are summarized in Table 6-5 and further detailed in Tables 6-7 and 6-8. Table 6-6 lists the percent significant difference that could be detected given the selected alpha level and power and observed variability. Table 6-6 is sorted in order of increasing percent detectable significant difference. These differences are the largest differences that might not be detected by the Wilcoxon rank sum test ($\alpha = 0.05$, power = 0.95), given the observed variability in each metric.

6.5.1 Abundance Measures

Plant abundance means the amount of plant material. There are three interrelated measurements or metrics (Table 6-2). They are:

- Percent cover—the proportion of area sampled that is covered by live plants.
- Stem density—the number of stems per plot.
- Biomass—the dry weight of all aboveground plant material.

Each metric is like a snapshot of the same fundamental entity (i.e., the plant community). The snapshots would be expected to show similar patterns of high or low expression relative to chemical contamination between the WBG and reference sites.

6.5.1.1 Percent cover

There was no statistically significant difference in percent cover between the contaminated burning pad sites and their respective reference sites. The values for individual plots ranged from 0 to 100% for pads 37 and 38 and pads E1 and E2 while the mean values were 83.3 and 80.9%, respectively. For pads 58 and 59 and pads S1 and S2, the range of values was 70 to 100% with mean values of 98.1 and 99.1%. For pads 66 and 67 and pads J1 and J2, the range was 30 to 100% with mean values of 92.8 and 99.5%. Table 6-4 summarizes these results as well as the statistics for the Wilcoxon rank sum test. Sample size was sufficient to statistically detect differences less than 20% with 95% power for pads 58 and 59 and pads 66 and 67. These statistical tests met all of the specified criteria and, therefore, allow us to conclude that there was no ecological effect on percent cover for pads 58 and 59 and pads 66 and 67. For pads 37 and 38, the detectable difference was 32% with 95% power (Table 6-8). This exceeded our specified criteria of 20% detectable difference. The mean biomass for pads 37 and 38, however, was actually higher than for the reference site. Figure 6-3 shows an example of low, medium and high percent cover. Appendix A (SAIC 2001) shows the individual plot data.

6.5.1.2 Stem density

Stem density, the mean number of stems per sample plot, was not statistically significantly different among any of the burning pad sites and reference sites sampled. The mean number of stems per square meter ranged from 1544 at pads E1 and E2 to 2197 at pads 66 and 67. The target power of 95% for a 20% significant difference was not met. For pads 58 and 59 and pads 66 and 67, a 43% significant difference could be detected at 95% power. For pads 37 and 38, a 70% significant difference could be detected with 95% power (Table 6-8). The detectable significant differences were larger than 20%, but it should be noted that the measured differences were small (<1%), or in the case of pads 37 and 38, in the opposite direction than would indicate impact. Appendix B (SAIC 2001) shows the names of the plant species and their stem counts.

6.5.1.3 Biomass

Vegetation biomass, which is the dry weight of plant material harvested from each 0.25-m^2 sample plot, was not statistically significantly different when burning pads were compared with their respective reference sites. The lowest mean biomass weight was 269 g dry weight/m^2 for reference site E2; the highest was 423 g dry weight/m^2 for pads 66 and 67. Given the variability of the measurements, the test could detect significant differences of about 30 to 70% at 95% power, depending on the pad examined (Table 6-8). The measured differences were lower than 20%, or in the case of pads 37 and 38, in the opposite direction than would indicate impact. Appendix A (SAIC 2001) provides the biomass data for each plot.

6.5.2 Plant Community Composition

As with abundance measures, there are three interrelated measurements of plant community composition (Table 6-2). They are:

- Species richness—the number of species present in sample area.

- Diversity index—the distribution of the number of individual stems among the species in the community sample.

- Percent exotic species—the number of species introduced from other environments and especially non-United States.

Each metric is like a snapshot of the same fundamental entity (i.e., the plant community). The snapshots would be expected to show similar patterns of high or low expression relative to chemical contamination between the WBG and reference sites.

6.5.2.1 Species Richness

The mean number of species per sample plot was not statistically significantly different between any of the burning pad sites and their respective reference sites. The mean number of species for all burning pad pairs ranged from 13.8 for pads 37 and 38 to 20.3 for pads 58 and 59. Pads 58 and 59 and 66 and 67 had, on average, more species than their respective reference sites. Sample size was sufficient for detecting a 25% significant difference for pads 58 and 59 and pads 66 and 67 and a 36% significant difference for pads 37 and 38 with 95% power (Table 6-8). The total number of species identified during the entire sampling process on all study sites was 109, of which 43 were exotic species and 66 were native plant species. Appendix B (SAIC 2001) contains a complete list of all species identified, and Table 6-7 lists the species, by percentage, comprising more than 1% of the total stems.

6.5.2.2 Diversity index

The community composition metric was calculated for the burning pad sites and reference sites. The Shannon Diversity Index (Table 6-2) expresses the relative abundance of all the species (the evenness of the species) and is most commonly used to express diversity. Diversity is considered an indicator of healthy plant communities. The Shannon Diversity Index was calculated from the stem density data. The higher the value of the Shannon Diversity Index, the more evenly abundance is spread among the species present for a given number of species (i.e., no few species dominate) or the more species present for a given evenness. The differences in diversity index between the reference and contaminated sites were less than 10% and were not statistically significant (Table 6-5). The CV, and thus the detectable difference, ranged from 27.9 to 38.5%. This means that the study team can be confident that the differences between the WBG burning pads and reference sites are less than 38.5%.

6.5.2.3 Percent Exotic Species

The comparisons of the percent of exotic species showed statistically significant differences between the contaminated sites and reference sites (Table 6-5). The percent of exotic species at pads 58 and 59 and 66 and 67 was more than twice as high as at their respective reference sites. The difference in percent exotic species was not statistically significant between pads 37 and 38 and its reference site. The percent of exotic species was higher at pads 37 and 38 (81.9%) than at the reference site (68.8%). The difference would need to be greater than 38.7% to be detectable statistically.

The significantly greater percentage of exotic species at pads 58 and 59 and 66 and 67 than at their respective reference sites raises the question of which species were more abundant at the WBG sites and which were more abundant at the reference sites. The Wilcoxon rank sum test was used to test for differences in the number of stems between the WBG and reference sites for the most abundant species. The test was applied for each species that represented at least 1% of the total number of stems counted over all of the WBG and reference sites.

There were 19 exotic species that comprised at least 1% of the total number of stems examined. All 19 species showed a statistically significant difference between the contaminated sites and reference sites for at least one of the pad pairs (Table 6-8). Canada blue grass, red fescue, redtop, common teasel, Queen Ann's lace, common yarrow, black medic, sharp-print fluellin, narrowleaf plantain, wild strawberry, and unidentified grass species tended to be more abundant in the contaminated than in the paired reference site. Poverty oat grass, broomsedge, devil's paint brush, smooth red goldenrod, old-field fivefinger, fuzzy

red goldenrod number 1, and Kentucky blue grass tended to be more abundant in the reference sites. These differences in species composition between the WBG burning pads and reference sites may be the effect of contamination at the WBG sites. If native species of plants were more inhibited by contamination than others, their abundance would be reduced relative to exotic species. The differences may also reflect types of seeds used to sow on bare areas at WBG (if any).

6.6 WEIGHT-OF-EVIDENCE CONSIDERATIONS

The approach taken for this qualitative weight-of-evidence is described in detail above. Basically, conclusions concerning the ecological status of the vegetation at the WBG sites are presented as propositions followed by the supporting evidence and a short summary of that evidence. These propositions evaluate ecological effects at WBG at the scale of the pad pairs. The scale of concern for ecological effects at WBG was a fundamental assumption of the experimental design and applies to all propositions presented here. After the propositions and evidence are presented, there is a discussion and uncertainties section followed by conclusions and summary.

Much of the supporting evidence is based on statistical tests. Statistics allow us to make quantitative estimates about the entire population of plants in an area based on the measurements of a sample of that population. In the supporting evidence below, we use the term 'population difference' to indicate an inference about the entire population of plants and use 'measured sample difference' for statements about the measured metrics of the sample taken.

Our confidence in how well our samples represent the pad pair population depends on the sample size and the natural variability of the vegetation metrics and the approaches used in the analysis of the data. Two approaches were used regarding the selection of sample numbers and the importance or confidence that was given to the results of the measurements. First by team consensus, a 20% difference between the WBG pad pairs and the reference sites was considered to be of ecological importance when the power of the test was equal to or greater than 95% percent with a corresponding alpha level of 5%. Results that met these criteria would be considered definitive regarding ecological impact or no-impact as the result of chemical contamination. Few of the results however, met these rigorous requirements and their prediction of ecological impact was mixed. The second method used to estimate sample size requirements and to evaluate the vegetation metrics results was based on the variability of the population measurements themselves. In this case, the sample size was chosen such that the Wilcoxon Rank Sum test would be able to detect, as statistically significant, differences equal to or greater than the variability of the measurements as represented by the coefficient of variation (CV). This method was based on selecting the significant difference to CV ratio on unity. Thereby acknowledging that aspects of the environment that have large amounts of variability, may require greater impacts before they have a negative effect on the population of interest. By using this method, results with a CV that exceeded 20% would not meet the statistical requirements to be considered definitive and therefore, a weight of evidence approach was used to evaluate these results.

In the following propositions, the CV is reported for tests that were not statistically significant to indicate how large the difference would need to be to be considered statistically significant by the test using the second method described above. In addition, tables are provided in section (xxx results) that present the confidence (*i.e.*, the power) of the test when the CV was greater than 20% with a corresponding alpha level of 5%. These confidence levels are based on the results that did not meet the statistical criteria that were to be considered definitive (*i.e.*, using the first method discussed above).

Proposition One: Chemical contamination does not cause an adverse effect on vegetation abundance at the WBG pads.

- Vegetation abundance was higher at pad pair 37/38 than at the reference site as indicated by the measured mean values of percent cover, stem density, and biomass. Although the variability of the measurements was high and the population differences were not statistically significant, the direction of the measured sample differences indicates a positive (higher abundance) rather than negative impact of contamination at pad pair 37/38.

- There were no statistically significant population differences between pad pair 58/59 and the matching reference site for each of the vegetation abundance metrics (percent cover, stem density, and biomass). The measured sample differences between the pad pair and the reference site were all less than 20%. Given the measurement variability as represented by the CV, the smallest statistically detectable differences would be 5% for percent cover, 43% for stem density, and 31% for biomass. We are, therefore, 95% confident that the population differences were less than 20% for percent cover but are less confident that the population differences were less than 20% for stem density and biomass.

- There were no statistically significant differences between pad pair 66/67 and the matching reference site for each of the vegetation abundance metrics (percent cover, stem density, and biomass). The measured sample differences between the pad pair and the reference site were all less than 20%. Given the measurement variability as represented by the CV, the smallest statistically detectable differences would be 15% for percent cover, 44% for stem density, and 46% for biomass. We are, therefore, 95% confident that the population differences were less than 20% for percent cover but are less confident that the population differences were less than 20% for stem density and biomass.

Considering all of the vegetation abundance information together, we see no evidence of a significant detrimental effect on vegetation abundance. There were no statistically significant differences for any of the vegetation abundance metrics (percent cover, stem density, and biomass) at any of the pad pairs. Although the confidence is less than 95% for most of the measurements, the measured sample differences were less than 20% for pad pairs 58/59 and 66/67, and for pad pair 37/38 the measured sample differences showed an increase rather than a decrease in vegetation abundance.

Proposition Two: Chemical contamination at WBG does not have an adverse impact on two of the three metrics of plant community composition (species richness and diversity index).

- There were no statistically significant differences between pad pair 37/38 and the matching reference site for species richness or diversity index. The measured sample differences between the pad pair and the reference site were all less than 20%. Given the measurement variability as represented by the CV, the smallest statistically detectable differences would be 37% for species richness and 39% for diversity index. So, we are less than 95% confident that the population differences were less than 20%.

- There were no statistically significant differences between pad pair 58/59 and the matching reference site for species richness and diversity index. The measured sample differences between the pad pair and the reference site were all less than 20%. Given the measurement variability as represented by the CV, the smallest statistically detectable differences would be 25% for species richness and 28% for diversity index. So, we are less than 95% confident that the population differences were less than 20%.

- There were no statistically significant differences between pad pair 66/67 and the matching reference site for species richness and diversity index. The measured sample differences between the pad pair and the reference site were all less than 20%. Given the measurement variability as represented by the

CV, the smallest statistically detectable differences would be 25% for species richness and 33% for diversity index. So, we are less than 95% confident that the population differences were less than 20%.

Considering the plant community composition information for all pad pairs, we see no evidence of a significant adverse effect on the number of species (species richness) or the evenness of distribution of individuals among species (diversity index). Although none of the measurements met the requirements to be considered definitive, there were no statistically significant differences (all measured sample differences were less than 20%) for either of these two metrics (species richness or diversity index) at any of the pad pairs.

Proposition Three: Chemical contamination at WBG has had an adverse impact on one of the metrics of plant community composition—the proportion of exotic plant species.

- The percent exotic species was 17.5% higher at pad pair 37/38 than its reference site, but the difference was not statistically significant. Given the measurement variability as represented by the CV, the smallest statistically detectable differences would be 39%.

- The percent exotic species was 119% higher at pad pair 58/59 than its reference site. The measured difference of 119% was larger than the CV of 58%. The difference was statistically significant with a probability less than 0.01.

- The percent exotic species was 115% higher at pad pair 66/67 than its reference site. The measured difference of 115% was larger than the CV of 84%. The difference was statistically significant with a probability less than 0.01.

All three WBG pad pairs had a higher percent exotic species than their reference sites. The differences were statistically significant for two of the pad pairs and met the statistical requirements to be considered definitive.

Proposition Four: Chemical contamination was estimated to have an adverse impact on vegetation based on traditional hazard quotient methodology. It should be noted that the HQs presented below are based on a recalculation of the original HQ values and represent a ratio of the soil contaminant concentration (95% UCL or maximum value and an arithmetic mean) and the corresponding soil benchmark value provided in the following hierarchy: Preliminary Remediation Goals for Ecological Endpoints, Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones, Aug 1997; Ecological Data Quality Levels (EDQL), U.S. EPA, Region 5, Final Technical Approach for Developing EDQLs for RCRA Appendix IX Constituents and Other Significant Contaminants of Ecological Concern, April 1999, http://www.epa.gov/reg5rcra/ca/edql.htm.

6.7 DISCUSSION AND UNCERTAINTIES

Spatial heterogeneity of soil contamination creates variation in the degree of plant exposure and in possible ecological effects. For example, the concentration of 2,4,6-trinitrotoluene was measured in eight samples on pad 67 within a 5-m radius of plot 132 (include ref). The concentrations ranged from 2.3 to 2,000 mg/kg, nearly a thousand-fold difference. There were also six plots within that same radius that were sampled for vegetation but not soil. While the assumption is that these vegetation plots had a similar concentration distribution to those plots where soil concentrations were measured, they could also be less contaminated or more contaminated.

The large spatial heterogeneity also raises the question of how reproducible the samples were. If the study were repeated would measurements result in the same conclusions? The question of reproducibility is quantified by the statistics that were used in the study. The measured CV values for the vegetation metrics provide a measure of the variation that may be expected if the study were repeated. For any metric, repeated sampling of the population should result in a set of mean values that is normally distributed with a standard error of the mean equal to the standard deviation divided by the square root of the number of measurements in the sample. The sample mean should be within two standard errors of the true population mean 95% of the time. (The question above was not answered other than to state the central limit theorem.)

The total area sampled in the field-truthing study was small (27 m^2 for 1-m^2 plots and 6.8 m^2 for 0.25-m^2 plots) relative to the size of the vegetation sampling grid (600 m^2 per pad pair) and relative to the areas of the burning pads (approximately 1080 m^2 for pad pair 37/38, 930 m^2 for 58/59 and 610 m^2 for 66/67). Given the sampling protocol and the size of the pads, the area sampled consisted of from 0.6% to 4.4% of the total pad area. Random sampling was conducted for the vegetation plots so that statistics could be used to extrapolate the results from the sample to represent the larger pad area. However, the total area sampled in relation to the contaminated areas (pad pairs) does add to and increase the uncertainty of the study.

The size and shape of the vegetation-sampling grid did not cover the entire pad area. Some areas of the pad were outside the sampling grid and, therefore, were not considered for sampling. This was particularly a problem for pad pair 37/38, which was the largest pad pair studied. The gridded area occupied 55% of the total pad. Using the Student-T test chemical concentrations inside the gridded area were not different when compared to respective concentrations outside the gridded area indicated that the soil concentrations were not significantly different in these adjacent areas and that the samples taken should, therefore, be representative of the entire pad pair.

It should be noted that there is an area of approximately 25 square feet of pad 67 devoid of vegetation as the result of chemical contamination (see pictures P6, P16 and P17). However, small patches of un-vegetated soils do not necessarily result in an ecological risk as they may or may not represent a large enough proportion of the total system and may or may not result in a loss or disruption of ecosystem function to the point the system is impaired. Even though the area is smaller in size than the pad-pair, which was considered the size of ecological importance, its presence may be of significance as a hotspot or for future site management.

The 1-m^2 quadrat approach is more difficult to apply in areas with woody vegetation than in areas with herbaceous vegetation. But, this could have been easily solved through use of a larger sampling area. There was little attempt to avoid trees and large bushes. In only one case, the orientation of the vegetation-sampling grid was altered to avoid a large woody shrub. There is a very large autumn olive at WBG pad 67. This bush was so large that it altered the microclimate at the site (most notably shade and soil moisture). It was decided that it would be better to change the orientation of the grid than to introduce the confounding influence of this plant on the microclimate at pad 67. The fact is that the highly disturbed areas – the burning pads and nearby areas – at RVAAP are physically and recently disturbed areas whose vegetative cover consists of low profile grasses and herbs found in the early stages or seres of ecological succession. Most of the other areas of concern at Ravenna have vegetative cover at earlier seres, i.e., even lower profile vegetation, or similar seres, i.e., similar to the appearance of the vegetation at the burning pads. Thus, any remediation is most likely to be completed on early seres or grassy cover areas and not forested areas.

Because burning was practiced historically on burning pads but not on reference pads, this difference in land use results in uncertainty about effects of burning on plant habitat (as opposed to chemical effects).

Reference sites were chosen to match the WBG sites with respect to soil type, hydrology, topography, degree of maintenance (i.e., mowing), and plant community type. Sites were also matched with respect to the time of the most recent disturbance. The burning that occurred on the WBG sites was a different type of disturbance than that which occurred at the reference sites. The burning that occurred at the WBG sites may have changed the organic content of the soils, destroyed seeds and rhizomes, and affected the soil structure and texture. Changes to the seed stock and physical structure of the soil from burning may affect the ability of vegetation to colonize and grow in these soils. Physical factors such as soil compaction and the presence of gravel and cinders will also preclude vegetative recolonization. There is, therefore, a discussion item as to whether the few differences in vegetation between the WBG and reference sites were caused by physical (i.e., fire and cinders) or chemical differences between the sites.

Variability of vegetation metrics resulted in a high coefficient of variation (CV>20%). The larger the variability in a measurement, the more difficult it is to detect differences between sites if differences exist. The planning team decided that differences between the WBG and reference sites that were greater than 20% would be considered ecologically significant. The sample size was chosen so that the difference between sites that could be detected was greater than or equal to the CV. Therefore, if the CV of a metric was 20% or less, any ecologically significant difference for that metric could be detected by the statistical test. When the CV of a metric was greater than 20%, for example 42.5% for stem density at pads 58/59 and reference sites S1/S2, only differences greater than 42.5% would be detected. If there was a difference between pads 58/59 and the reference site that was less than 42.5%, the statistical test ~~may~~ could not detect it. However, based on the statistical design one would expect detectable significant differences to be high with a high coefficient of variation. Setting the significant difference/CV ratio to one means that the sample size should be sufficient to detect a significant difference as large as the standard deviation. When the CV was greater than 20%, there was the possibility that a difference greater than 20%, and therefore, ecologically important, would not be detected by the statistical test.

Biological correlation between and among plant measurements can vary because of interdependence or interaction of vegetation characteristics in nature. For example, percent cover, species richness, and biomass are all measures of the quantity of vegetation present. They would be expected to show a strong positive correlation. This correlation would add credibility to the interpretation of the results. The results for different metrics are not independent lines of evidence but are, instead, different measures of the same basic biological entity.

Species composition differences between pads and reference sites (cause/effect) are difficult to understand. In order to make the sampling and statistics manageable, we have assumed that the characteristics being measured were randomly distributed across the pads. In reality, species distributions are affected by the way in which each plant propagates. When a large area is disturbed, those species that colonize or invade are those whose seeds can withstand the disturbance or can be transported from an undisturbed area. The seeds and vegetative reproductive structures (rhizomes, stolons, bulbs, corms) of the colonizing species will tend to be most abundant in close proximity to the colonizing plant. This creates an overlapping, patchy pattern for each species' coverage. Because of the geographical distance between the WBG and reference sites, we cannot assume that the same species are equally likely to colonize after a disturbance at each site. Also, the type of disturbance, especially burning, at WBG may have destroyed seed stock that was not destroyed by the disturbances at the reference sites.

The exotic plant species found on the WBG and most of the vegetation sampled on the pad pairs and reference locations are r-selected (i.e. tolerant, highly reproductive, low nutrient requiring) primary invaders of disturbed sites. Physical disturbance related to WBG operations such as frequent burning, soil disturbance, and compaction produce conditions that are ideal for r-selected plant species colonization to include exotic species. Physical disturbance factors have as great an influence, if not greater, on exotic plant colonization as chemical contamination. Repeated chemical and physical (including fire)

disturbances, as have occurred at the WBG pad pairs, provided an opportunity for the colonization by exotic plant species. The presence of exotic species does not necessarily cause a significant detrimental ecological impact as these plant species may provide similar erosion control, animal habitat and food for the ecosystem as do native species.

The data from the reference sites suggest that recent disturbance may have an effect on the percent exotic species. The most recently disturbed reference site E1/E2 had 68.8% exotic species compared with 17% at S1/S2 and 10.3% at J1/J2. Looking over all WBG and reference sites, the percent exotic species appears to decrease with time since the last physical disturbance (Table 5-8 in April 2001 report). The methods of plant dispersion, along with the differences in disturbance between the WBG and reference sites, introduce the need for careful interpretation of species composition differences.

The number of identifiable species may vary with season, but the WBG reference sites were compared by the same observers in the same season so that the relative comparisons are valid. The comparison process was methodical over an eight-week period with a team of persons who were familiar with the watersheds, soils, vegetation, animals, and especially the history of past physical and other perturbations. For example, team members consisted of Ravenna environmental stewards and environmental workers (both Ohio Army National Guard and the Army) and experienced ACE and experienced SAIC environmental workers. There was a careful process of selecting the reference sites and matching each one of them to the appropriate WBG pads. Further, field biologists visited the various reference and various WBG sites in a random way so that the growth of vegetation and especially biomass would not be biased. Regarding species identifications, field biologists succeeded in identifying almost all the species by complete common name and complete scientific name; where this was not possible, they termed the species no. 1, no. 2 and so forth within a given genus or family. With the exception of the grass genus *Festuca*, the few unidentifiable species had few stems. Thus, in regards to the identification of plant species and the possible confounding affects due to temporal variations in the plant community, there is confidence in the comparisons of plant metrics from the pads to the reference areas.

We have little information concerning the tolerance/intolerance of plant species to the chemicals found at WBG. Much of the literature on the effects of chemicals on plants concerns commercially and agriculturally important plant species rather than native vegetation. Of course, knowing the sensitivity of specific plant species to specific chemicals would help determine if there is a causal link between the distribution of chemicals at WBG and the measured differences in the distributions of exotic species. A literature search was conducted to find toxicity information relating the plant species observed at the burning pads to the contaminants found at the burning pads. We were not surprised to find no data about mixtures of chemicals like the chemicals at WBG to field-observed effects to the various plant species. The phytotoxicity literature, i.e., knowledge about plant sensitivities to the chemicals, rarely contains the type and quality of information needed. Thus, one way to solve this matter was to conduct the field-truthing study on the vegetation.

All of the sites studied were at a stage of ecological succession. The soil, plants, and animals were in transition from a disturbed condition to a more stable community structure. The availability of colonizing species may cause differences in the successional conditions from site to site. This adds another element to the discussion about the WBG/reference site comparisons.

6.8 CONCLUSIONS AND SUMMARY

The biological field-truthing effort at WBG included carefully designed field measurements at the pad scale, statistical analysis, weight-of-evidence discussion and uncertainty evaluation. The following conclusions and summary concerning vegetation may be drawn from these efforts:

1. The field-truthing approach provided valuable information that reduces concern raised by the hazard quotients. Thus, the observed facts and weight of evidence may support the absence of concern for vegetation at the scale of the pads. There was much evidence (see above propositions and evidences) that vegetation is healthy when compared to the reference locations.

2. The chemical contamination in the soil at WBG does not appear to have caused an ecological impact on the vegetation abundance at the pad scale.

3. The chemical contamination in the soil at WBG does not appear to have caused an ecological impact on the plant community composition with respect to species richness and species diversity at the pad scale.

~~4.~~ The chemical contamination in the soil at WBG may have caused an impact on the plant community composition with respect to the percent exotic species. The percent exotic species was higher at the WBG pad pairs than the respective reference sites.

5. HQs for some constituents do exceed unity.

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FIGURES

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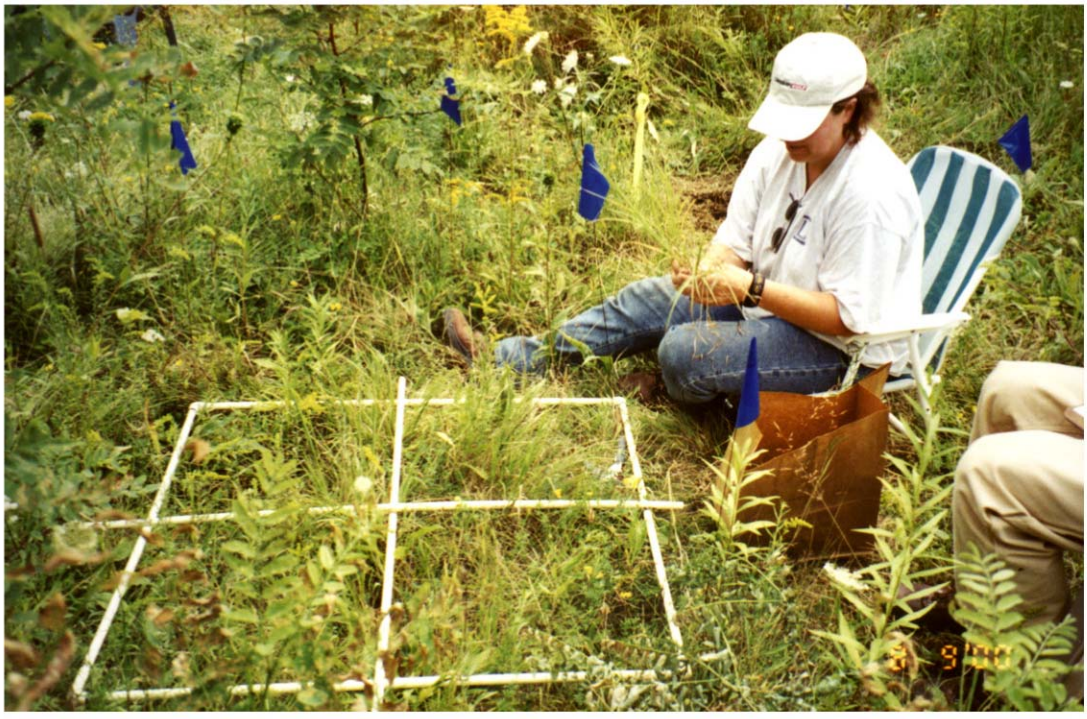
Figure 6-1. Biomass Sampling at Winklepeck Burning Ground Pad 67 Sampling Site



59-030601-061 M

Figure 6-2. Biomass Sampling at Winklepeck Burning Ground Pad 59 Sampling Site

Figure 6-3. Three Plots with Varying Cover at Winklepeck Burning Ground Pad 67 Sampling Site

TABLES

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Table 6-1. Summary of Potential Methods for Assessing Impacts to Vegetation at WBG, RVAAP, Ohio

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
Vegetation Community Measures									
1	Percent cover	Measurements of cover types in terms of percent cover of a given area size	Higher the percent cover the better	Fundamental ecological measure; need to obtain estimate of what vegetation is present	Several days	Applicable to all habitats where vegetation is present	Probably low, but there are seasonal influences	Daubenmire (1959); Bonham (1989): Diersing et al. (1992); Tazik et al. (1992)	Recommended for protocol
2	Community composition	List of species observed and number of each species	Greater number of species the better, minus exotics	Fundamental ecological measure; need to obtain estimate of what vegetation is present	Several days	Applicable to all habitats where vegetation is present	Probably high; seasonal factors	Kapustka (1989)	Recommended for protocol
3	Density	Number of stems or plants/area	Generally, the higher the better, but should be in equilibrium with carrying capacity	Fundamental ecological measurement; vegetation tends towards the carrying capacity of the habitat	Several days, but longer than canopy cover	Applicable to all habitats where vegetation is present	Probably moderate	Kapustka (1989)	Not recommended for protocol
4	Biomass estimates	Data expressed as kilograms (kg)/area	Generally, the higher the better	Fundamental ecological measurement; used to indicate production in the vegetation community	Several days (field) plus several days lab analyses	Applicable to all habitats where vegetation is present	High, especially in short-term study; seasonal factors	Kapustka (1989)	Not recommended for protocol
5	Frequency	Distribution of individuals	Generally, the higher the frequency, the better	Information provided on the distribution of the species	Few days (simple, rapid, objective)	The frequencies are dependent on the species and plant size. The estimates should be between 20 to 80% within a quadrant to best detect changes.	Probably moderate to high	Winward and Martinez (1983); Curtis and McIntosh (1950)	Not recommended for the protocol

Table 6-1. Summary of Potential Methods for Assessing Impacts to Vegetation at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
Vegetation Diversity Measures									
6	Species counts	Number of species per unit area	More species the better	Species diversity is one of the most important aspects of community structure; this is the simplest measure of diversity	Several days of fieldwork	Applicable to all potential habitats where vegetation is present	Probably high	Kapustka (1989)	Has two main drawbacks: (1) unweighted and fails to account for relative abundances, (2) depends on sample size; not recommended for the protocol
7	Shannon-Wiener Function (H')	Probability that 2 individuals selected at random from a community of N individuals are from the same species	Greater the index, the better	Species diversity is one of the most important aspects of community structure	May need few days to couple weeks of sampling	Applicable to all habitats where vegetation is present; appropriate when all individuals in the community cannot likely be counted	Probably high	Hair (1980)	Only requires a random sample from community, not all individuals; not recommended for the protocol because lengthy sampling and high variability
Vegetation Biomarkers									
8	Symbiont Measures (Vesicular Arbuscular Mycorrhi-zae)	Mycorrhizae species lists and abundances	The presence or the higher the numbers of key microbial taxa the better	Health of most plants dependent on microbial flora in the root systems	Moderate for field sampling; lab analysis moderate?	Best where abundant number of individuals expected	Probably high	Kapustka (1989)	EPA method (traditional), indirect measure of stress. Recommended for protocol.
9	Photosyn-thetic process (CO_2 uptake)	Uptake of CO_2 per unit of time	Higher the rate of CO_2 uptake the better	Photosynthesis is fundamental metabolic process for living plants; decreases in it indicate stress to the plant	Moderate for field sampling	Must have portable field instruments and skilled personnel to operate them; also need live plants for sampling	Probably high	Kapustka (1989)	Not recommended for protocol
10	Chlorophyll a content	Chlorophyll a content in tissue	Higher concentrations are better than lower	Indicator of photosynthesis potential	Few days for field sampling; plus time for lab analysis	Need live plants for sampling	Probably moderate	To be determined	Not recommended for protocol

Table 6-1. Summary of Potential Methods for Assessing Impacts to Vegetation at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
Chemical Analyses of Plant Tissues									
11	Inorganics in vegetation tissue (leaves and/or roots)	Milligrams (mg) contaminant/kg tissue	The lower the concentrations, the better	Indicates exposure to and bioacummulation of inorganic contaminants by small mammals	Collection can take days; analysis quick	Where vegetation is present at contaminated soils	Probably low to moderate	EPA (1986)	Potentially recommended for protocol, especially if linked to small mammals
12	Organics in vegetation tissue (leaves and/or roots)	mg contaminant/ kg tissue	The lower the concentrations, the better	Indicates exposure to and bioacummulation of organic contaminants by small mammals	Collection can take days; analysis quick	Where vegetation is present at contaminated soils	Probably low to moderate	EPA (1986)	Potentially recommended for protocol, especially if linked to small mammals
Plant Toxicity Tests (population measures)									
13	Seed germination (ASTM E1598-94)	Percentage of germinated seeds	The greater the percentage of germination, the better	Germination necessary to perpetuate the population	Collection in 1to 2 days; test takes up to 28 days (at least 21 days after 50% of control plants have emerged)	Need bulk soil sample; also need various physicochemical soil parameters to differentiate non-contaminant effects	Generally low to moderate	ASTM (1998)	Potentially recommended for protocol
14	Percent survival (ASTM E1598-94)	Percentage of seedlings that survive to end of test	The greater the percentage of survival, the better	Survival indicates potential to perpetuate the population	Collection in 1 to 2 days; test takes up to 28 days (at least 21 days after 50% of control plants have emerged)	Need bulk soil sample; also need various physicochemical soil parameters to differentiate non-contaminant effects	Generally low to moderate	ASTM (1998)	Potentially recommended for protocol
15	Root elongation (ASTM E1598-94)	Mean root length	The greater the elongation, the better	Increased growth indicates potential higher fitness of the plant	Collection in 1 to 2 days; test takes up to 28 days (at least 21 days after 50% of control plants have emerged)	Need bulk soil sample; also need various physicochemical soil parameters to differentiate non-contaminant effects	Generally low to moderate	ASTM (1998)	Potentially recommended for protocol

ASTM = American Society for Testing and Materials.

Table 6-2. Vegetation Parameters Sampled at WBG

Parameter	Definition	Measurement
Percent Cover	Proportion of area sampled that is covered with plants	Percent pins touching in 1-m^2 plots
Stem Density	Number of stems per plot	Counts in 0.25-m^2 plots within 1-m^2 plots
Biomass	Dry weight of all aboveground plant material	Mass (mg) in 0.25-m^2 harvested within 1-m^2 plots
Species Richness	Number and list of species present in sample area	Counts in 1-m^2 plots
Community Composition	Shannon Diversity Index[a] used to express relative abundance of all species present	Calculated for 0.25-m^2 plots within 1-m^2 plots
	Proportion of exotic species	Number of stems of exotic species divided by total number of stems in 0.25-m^2 plots

[a]Shannon Diversity Index H′ indicates how evenly plant abundance is divided among the given number of species. Values near zero indicate that most plants are in one or a few species. High values indicate plants spread over many species. For a given evenness, H′ increases with the number of species (richness).

$$H' = -\sum_{i=1}^{S} p_i \log p_i$$

where

H′ = Shannon Diversity Index,
S = number of species in 0.25-m^2 plot,
i = species index,
$p_i = n_i/N$,
n_i = number of stems for the i^{th} species in plot,
N = total number of stems in 0.25-m^2 plot,
log = natural logarithm.

Table 6-3. Random Status of Samples

	Pad 37		Pad 38		Pad 58		Pad 59		Pad 66		Pad 67	
	Plot	**Random**	**Plot**	**Random**	**Plot**	**Random**	**Plot**	**Random**	**Plot**	**Random**	**Plot**	**Random**
	225	NR	154	R	104	NR	249	R	243	NR	132	NR
	173	NR	126	R	251	NR	160	R	242	NR	133	NR
	236	NR	30	R	234/235	NR	274	R	73	R	128	NR
	265	R	135	R	156	NR	253	R	152	R	134	NR
	270	R	284	R	158	R	262	R	2	R	127	NR
	188	NR	5	R	72	R	194	R	15	R	142	R
	130	NR	267	R	21	R	125	R	31	R	136	R
	110	NR	248	R	44	R	213	R	65	R	120	NR
	179	R	264	R	45	R	216	R	88	R	131	R
	11	R	295	R	184	R	111	R	111	R	105	NR
	50	R	270	R	285	R	145	R	123	R	244	R
	74	R	234	R	189	R	188	R	218	R	245	R
	123	R	97	R	201	R	207	R	226	R	265	R
	15	R	16	R	190	R	108	R	249	R	106	R
	42	R	230	R	94	R	140	R	265	R	15	R
	5	R			121	R			282	R	217	R
	31	R									29	R
	67	R									204	R
											35	R
											121	R
Total	18		15		16		15		16		20	

NR = Nonrandom.
R = Random.

Table 6-4. Comparison of Vegetation Abundance Measurements Between Contaminated and Reference Sites at Winklepeck Burning Grounds

Contaminated Sites					Reference Sites						
Pads	Mean[a] and Distribution	CV	Minimum	Maximum	Reference Sites	Mean[b] and Distribution	CV	Minimum	Maximum	Probability for Wilcoxon Test[c]	Percent Difference[d]
Percent Cover											
37/38	83.3[e]	27.8	7	100	E1/E2	80.9[e]	36.8	0	100	0.97	3.0
58/59	98.1[e]	6.00	70	100	S1/S2	99.1[e]	2.03	91	100	0.93	-1.0
66/67	92.8[e]	22.0	30	100	J1/J2	99.5[e]	1.64	92	100	0.54	-6.9
Species Richness (taxa/m^2)											
37/38	13.8[f]	29.9	5	25	E1/E2	14.3[f]	41.6	0	24	0.37	-3.4
58/59	20.3[f]	22.9	13	30	S1/S2	18.4[f]	27.4	10	31	0.14	10.0
66/67	15.9[f]	30.0	7	27	J1/J2	15.2[f]	16.8	8	20	0.80	4.7
Stem Density (stems/m^2)											
37/38	2195[f]	66.1	12	5532	E1/E2	1544[f]	74.5	0	3916	0.10	35.2
58/59	1675[f]	37.9	440	3144	S1/S2	1689[f]	46.2	400	3380	1.00	-0.8
66/67	2197[f]	42.1	444	4144	J1/J2	2196[f]	44.2	512	3948	0.97	0.0
Biomass (g dry weight/m^2)											
37/38	411[f]	67.8	5.2	898	E1/E2	269[f]	75.1	-2.8	794	0.07	42.3
58/59	361[f]	26.9	186	565	S1/S2	404[f]	33.2	154	641	0.16	-11.3
66/67	423[f]	56.7	45.2	868	J1/J2	405[f]	29.4	224	656	0.93	4.5

[a]Statistics were calculated on results from 27 randomly selected plots from each contaminated site.
[b]Statistics were calculated on results from 30 randomly selected plots from each control area.
[c]All probabilities for Wilcoxon rank sum two-tailed tests are greater than 0.05 and are, therefore, considered not significant.
[d]Calculated as 100 times (mean for contaminated site minus mean for reference site)/overall mean.
[e]Distribution different from normal based on Shapiro-Wilk test ($p < 0.05$).
[f]Distribution not different from normal based on Shapiro-Wilk test ($p \geq 0.05$).

CV = Coefficient of variation.

Table 6-5. Comparison of Vegetation Species Composition Measurements Between Contaminated and Reference Sites at Winklepeck Burning Grounds

Contaminated Sites					Reference Sites						
Pads	**Mean[a] and Distribution**	**CV**	**Minimum**	**Maximum**	**Reference Sites**	**Mean[b] and Distribution**	**CV**	**Minimum**	**Maximum**	**Probability for Wilcoxon Test[c]**	**Percent Difference**
Exotic Species Stem Count/Total Stem Count %											
37/38	81.9[d]	29.5	0.00	100	E1/E2	68.8[d]	48.0	3.14	100	0.25	17.5
58/59	63.4[d]	45.0	9.49	95.7	S1/S2	17.0[d]	88.9	0.75	61.2	0.00	119
66/67	36.2[d]	71.8	5.57	94.2	J1/J2	10.3[d]	82.0	1.85	38.5	0.00	115
Diversity Index											
37/38	1.40[e]	34.8	0.00	2.35	E1/E2	1.53[e]	41.1	0.00	2.52	0.25	-8.7
58/59	1.70[e]	28.6	0.80	2.74	S1/S2	1.79[e]	27.4	0.80	2.70	0.56	-5.7
66/67	1.31[e]	37.2	0.45	2.50	J1/J2	1.43[e]	29.9	0.55	2.01	0.29	-8.2

[a]Statistics were calculated on results from 27 randomly selected plots from each contaminated site.
[b]Statistics were calculated on results from 30 randomly selected plots from each control area.
[c]Probabilities for Wilcoxon rank sum two-tailed tests less than 0.05 were considered significant and are in bold type.
[d]Distribution not different from normal based on Shapiro-Wilk test ($p \geq 0.05$).
[e]Distribution different from normal based on Shapiro-Wilk test ($p < 0.05$).

CV = Coefficient of variation.

Table 6-6. Percent Significant Difference of Vegetation Measurements Detectable with 95% Power at a 5% Alpha Level between Contaminated and Reference Sites at Winklepeck Burning Grounds

Measurement	Paired Groups	Percent Significant Difference Detectable with 95% Power at 5% Alpha	Pooled CV
Significant Difference Detectable 20% or Less			
Percent Cover	58/59:S1/S2	4.3	4.4
Percent Cover	66/67:J1/J2	14.5	14.6
Significant Difference Detectable 20% to 40%			
Species Richness (taxa/m^2)	66/67:J1/J2	24.1	24.3
Species Richness (taxa/m^2)	58/59:S1/S2	25.0	25.2
Diversity Index	58/59:S1/S2	27.7	27.9
Biomass (g dry weight/m^2)	58/59:S1/S2	30.5	30.8
Percent Cover	37/38:E1/E2	32.5	32.7
Diversity Index	66/67:J1/J2	33.0	33.3
Species Richness (taxa/m^2)	37/38:E1/E2	36.5	36.7
Diversity Index	37/38:E1/E2	38.2	38.5
Exotic Species Stem Count/Total Stem Count	37/38:E1/E2	38.4	38.7
Significant Difference Detectable 40% to 60%			
Stem Density (stems/m^2)	58/59:S1/S2	42.2	42.5
Stem Density (stems/m^2)	66/67:J1/J2	42.8	43.2
Biomass (g dry weight/m^2)	66/67:J1/J2	44.7	45.1
Exotic Species Stem Count/Total Stem Count	58/59:S1/S2	57.2	57.7
Significant Difference Detectable 60% or Greater			
Stem Density (stems/m^2)	37/38:E1/E2	69.7	70.2
Biomass (g dry weight/m^2)	37/38:E1/E2	71.2	71.8
Exotic Species Stem Count/Total Stem Count	66/67:J1/J2	83.1	83.8

CV = Coefficient of variation.

Table 6-7. List of Species Comprising More than 1% of Total Number of Stems

Common Name	Scientific Name	Stems (%)
Poverty oat grass	*Danthonia compressa*	21.5
Grass	*Festuca* spp	15.8
Canada blue grass	*Poa compressa*[a]	8.9
Red fescue	*Festuca rubra*[a]	8.6
Redtop	*Agrostis gigantea*[a]	7.4
Common teasel	*Dipsacus sylvestris*[a]	4.7
Broomsedge	*Andropogon virginicus*	3.2
Queen Anne's lace	*Daucus carota*[a]	2.4
Devil's paint-brush	*Hieracium aurantiacum*[a]	2.2
Ox-eye daisy	*Chrysanthemum leucanthemum*[a]	2.1
Common yarrow	*Achillea millefolium*	1.9
Black medic	*Medicago lupulina*[a]	1.9
Smooth red goldenrod	*Solidago 1*	1.8
Sharp-point fluellin	*Kickxia elatine*[a]	1.7
Old-field fivefinger	*Potentilla simplex*	1.5
Fuzzy red goldenrod # 1	*Solidago 2*	1.5
Narrowleaf plantain	*Plantago lanceolata*[a]	1.3
Kentucky blue grass	*Poa pratensis*[a]	1.2
Wild strawberry	*Fragraria virginiana*	1.1
Total %		90.9

[a]Exotic species.

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Table 6-8. Comparison of Species Composition Between Contaminated and Reference Sites at Winklepeck Burning Grounds

Contaminated Sites				Reference Sites					
Pads	**Mean[a] and Distribution**	**Minimum**	**Maximum**	**Reference Sites**	**Mean[b] and Distribution**	**Minimum**	**Maximum**	**Probability for Wilcoxon Test[c]**	**Percent Difference**
Poverty oat grass (Danthonia compressa)									
37/38	12[d]	0	316	E1/E2	261[d]	0	2476	**0.03**	-174
58/59	291[d]	0	2064	S1/S2	655[d]	0	1760	**0.00**	-75
66/67	24[d]	0	376	J1/J2	1132[d]	36	3176	**0.00**	-182
Grass (Festuca spp)									
37/38	99[d]	0	1144	E1/E2	0	0	0	**0.02**	211
58/59	49[d]	0	1240	S1/S2	56[d]	0	1080	0.34	-14
66/67	1059[d]	0	3452	J1/J2	581[d]	116	1316	0.19	59
Canada blue grass (Poa compressa)									
37/38	323[d]	0	880	E1/E2	219[d]	0	1672	**0.01**	39
58/59	386[d]	28	960	S1/S2	55[d]	0	336	**0.00**	157
66/67	55[d]	0	500	J1/J2	13[d]	0	228	0.87	126
Red fescue (Festuca rubra)									
37/38	170[d]	0	1764	E1/E2	222[d]	0	1324	0.27	-26
58/59	340[d]	0	1924	S1/S2	22[d]	0	356	**0.01**	184
66/67	264[d]	0	2488	J1/J2	0	0	0	**0.02**	211
Redtop (Agrostis gigantea)									
37/38	537[d]	0	2768	E1/E2	176[d]	0	920	**0.01**	104
58/59	72[d]	0	344	S1/S2	26[d]	0	244	**0.00**	97
66/67	60[d]	0	928	J1/J2	1	0	12	**0.00**	207
Common teasel (Dipsacus sylvestris)									
37/38	461[d]	0	2620	E1/E2	1[d]	0	16	**0.00**	211
58/59	0	0	0	S1/S2	0	0	0	1.00	0
66/67	113[d]	0	996	J1/J2	0	0	0	**0.00**	211
Broomsedge (Andropogon virginicu)									
37/38	0	0	0	E1/E2	3[d]	0	84	0.36	-190
58/59	10[d]	0	172	S1/S2	330[d]	0	1308	**0.00**	-179
66/67	0	0	0	J1/J2	3[d]	0	56	0.18	-190
Queen Anne's lace (Daucus carota)									
37/38	90[d]	0	368	E1/E2	91[d]	0	456	0.21	-2
58/59	58[d]	0	544	S1/S2	7[d]	0	100	**0.00**	161
66/67	35[d]	0	136	J1/J2	1[d]	0	16	**0.00**	196

Table 6-8. Comparison of Species Composition Between Contaminated and Reference Sites at Winklepeck Burning Grounds (continued)

Contaminated Sites				Reference Sites					
Pads	Mean[a] and Distribution	Minimum	Maximum	Reference Sites	Mean[b] and Distribution	Minimum	Maximum	Probability for Wilcoxon Test[c]	Percent Difference
Devil's paint-brush (Hieracium aurantiacu)									
37/38	0	0	4	E1/E2	5[d]	0	52	**0.03**	-179
58/59	17[d]	0	104	S1/S2	58[d]	0	464	**0.02**	-105
66/67	32[d]	0	228	J1/J2	132[d]	0	520	**0.00**	-119
Ox-eye daisy (Chrysanthemum leucan)									
37/38	28[d]	0	240	E1/E2	95[d]	0	432	**0.00**	-107
58/59	26[d]	0	128	S1/S2	35[d]	0	304	0.54	-31
66/67	53[d]	0	400	J1/J2	4[d]	0	36	0.00	177
Common yarrow (Achillea millefolium)									
37/38	23[d]	0	132	E1/E2	4[d]	0	100	**0.00**	152
58/59	52[d]	0	312	S1/S2	7[d]	0	128	**0.00**	160
66/67	117[d]	0	456	J1/J2	28[d]	0	220	**0.00**	128
Black medic (Medicago lupulina)									
37/38	66[d]	0	240	E1/E2	96[d]	0	688	0.78	-37
58/59	38[d]	0	220	S1/S2	0	0	4	**0.00**	210
66/67	17[d]	0	132	J1/J2	1[d]	0	16	**0.00**	198
Smooth red goldenrod (Solidago 1)									
37/38	6[d]	0	32	E1/E2	9[d]	0	92	0.76	-48
58/59	25[d]	0	124	S1/S2	85[d]	0	204	**0.00**	-106
66/67	40[d]	0	184	J1/J2	36[d]	0	184	0.93	11
Sharp-point fluellin (Kickxia elatine)									
37/38	203[d]	0	3500	E1/E2	0	0	0	**0.03**	211
58/59	0	0	0	S1/S2	0	0	0	1.00	0
66/67	0	0	0	J1/J2	0	0	0	1.00	0
Old-field fivefinger (Potentilla simplex)									
37/38	0	0	0	E1/E2	38[d]	0	332	**0.00**	-190
58/59	38[d]	0	276	S1/S2	15[d]	0	48	0.82	91
66/67	3[d]	0	24	J1/J2	76[d]	0	344	**0.00**	-176

Table 6-8. Comparison of Species Composition Between Contaminated and Reference Sites at Winklepeck Burning Grounds (continued)

Contaminated Sites				Reference Sites					
Pads	Mean[a] and Distribution	Minimum	Maximum	Reference Sites	Mean[b] and Distribution	Minimum	Maximum	Probability for Wilcoxon Test[c]	Percent Difference
Fuzzy red goldenrod #1 (Solidago 2)									
37/38	16[d]	0	88	E1/E2	40[d]	0	224	**0.02**	-83
58/59	40[d]	0	220	S1/S2	25[d]	0	144	0.17	47
66/67	35[d]	0	248	J1/J2	17[d]	0	60	0.21	67
Narrowleaf plantain (Plantago lanceolata)									
37/38	53[d]	0	156	E1/E2	23[d]	0	340	**0.00**	83
58/59	31[d]	0	124	S1/S2	0	0	0	**0.00**	211
66/67	49[d]	0	224	J1/J2	0	0	0	**0.00**	211
Kentucky blue grass (Poa pratensis)									
37/38	6[d]	0	120	E1/E2	122[d]	0	1740	**0.02**	-174
58/59	0	0	0	S1/S2	2[d]	0	60	0.36	-190
66/67	0	0	0	J1/J2	0	0	0	1.00	0
Wild strawberry (Fragraria virginiana)									
37/38	6[d]	0	140	E1/E2	2[d]	0	60	0.55	102
58/59	42[d]	0	124	S1/S2	9[d]	0	76	**0.00**	136
66/67	31[d]	0	156	J1/J2	35[d]	0	144	0.10	-14

[a]Statistics were calculated on results from 27 randomly selected plots from each contaminated site.
[b]Statistics were calculated on results from 30 randomly selected plots from each control area.
[c]Probabilities for Wilcoxon rank sum two-tailed tests less than 0.05 were considered significant and are in bold type. Tests with P values less than 0.05 indicate that the abundance of that species is significantly different between the burning pads and their paired reference sites.
[d]Distribution different from normal based on Shapiro-Wilk test ($p < 0.05$).
[e]Distribution not different from normal based on Shapiro-Wilk test ($p \geq 0.05$).

Table 6-9. Exotic Species Related to Study Site/Reference Site Disturbance History

Location	Expected Likelihood of Increased Exotics	Exotic Species Stem Count/ Total Stem Count Expressed as % (See Table 6-5)	Site Disturbance		
			Type Including Purpose/Description of Past Usage	Period Used by RVAAP	Duration
Pads 37/38	High	81.9	Open burning of explosive waste, RCRA open burning area; area has had highest amount of traffic of all six study/reference sites	Mid-1940s to early 1990s	50 years
Pads 58/59	High	63.4	Open burning of explosives and household rubbish	Mid-1940s to early 1980s	40 years
Pads 67/68	Medium	36.2	Open burning of explosive waste; not used as much as 37/38, 58/59	Mid-1940s to early 1980s	40 years
Ref E1/E2	Medium	68.8	Ohio National Guard field hospital site	1989–1992	3 years
Ref S1/S2	Low	17.1	Borrow source for fill; no traffic or usage since	Early 1940s	A few years
Ref J1/J2	Low	10.3	Airstrip to land four C-46 and thirteen C-82 airplanes for the NACA test crash program	1949–1951	2 years

NACA = National Advisory Committee on Aeronautics.
RCRA = Resource Conservation and Recovery Act of 1976.
RVAAP = Ravenna Army Ammunition Plant.

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7.0 SMALL MAMMALS

7.1 RATIONALE AND BACKGROUND

Mammals constitute an important group of ecological resources. Mammals eat vegetation and regulate it. Mammals, in turn, are eaten by other organisms and aid in maintaining the web of nature. Many mammals live at WBG, and their community and reproductive status were selected as an objective of study in the field investigation. The purposes, statistical methods, and locations of this investigation are explained in Chapters 1.0 (Introduction), 2.0 (Scope and Objectives), 3.0 (Statistical Design), and 4.0 (Study Sites). This chapter describes the rationale and methods used for sampling and evaluating small mammal reproduction status at both contaminated burning pad sites and reference sites at WBG.

Consistent with EPA guidance for ERAs (EPA 1997, 1998), HQs were initially calculated for 70 burning pad sites during the Phase II RI for WBG (USACE 2001). These HQs served as ecological health screening tools for mammal and bird receptors of interest. After consideration of the background chemical concentrations in soil, seven burning pads were recognized as continuing to pose an ecological health concern to small mammal species, which serve as surrogates for a much greater list of terrestrial receptors at WBG.

The receptors with excessive HQs in the Phase II RI would ideally be those collected in the field-truthing effort. Therefore, small mammals were selected for the field-truthing efforts. Small mammals are often used as bioindicators for ecotoxicity studies (Ma 1989). Small rodents are often used because of their availability, smaller home ranges, food habitats, and vulnerability to soil contamination (Ma 1989, Pascoe et al. 1996, Reinecke et al. 2000). It is not practical to collect fox, hawks, and other higher trophic level terrestrial receptors from both WBG and matched reference locations for comparison purposes. Furthermore, the appropriate measurements to compare would need to be developed for these species. Small rodents are clearly more practical to use, because they are expected to be plentiful at WBG, relatively easy to trap, have limited home ranges on the order of the study pad areas, and acceptable methods for collecting and euthanizing them are readily available.

Initially, information about 22 methods for measuring various attributes of small mammals was gathered and organized into 4 types of measurements: small mammal population analytical measures, diversity measures (community), small mammal biomarkers, and chemical analyses of mammals and their prey tissues. Four selection criteria were applied to each of the 22 methods. These criteria were ecological significance of method, amount of work involved, where the method works best, and variability of the method (Table 7-1). These criteria were combined to recognize the following best 4 of the 22 methods: small mammal population density, rodent sperm analysis, liver tissue cytochrome P-450, and contaminant analysis in plants and animals (SAIC 1999a). During development of the SAP (SAIC 2000), reproductive condition was selected to compare the condition of small mammals at the burning pad sites with the small mammals at the reference sites. The metrics for reproductive condition were sperm motility, sperm counts, and sperm morphology as measured in the on-site laboratory (Table 7-2). Relative abundance and species compositions were additional measures where the emphasis was field-observed measurements.

The field-truthing effort for small mammals at WBG was geared to identifying reproductive impacts in two regards. First, with only one exception, every HQ greater than 1.0 at the burning pads of interest (USACE 2001) was derived from a TRV with a reproductive endpoint (e.g., litter size, number of litters). A legitimate concern that reproductive impacts were possibly present for a variety of mammal species led to the field-truthing effort. Second, the ultimate concern for any chemically exposed receptor is that it be able to perpetuate itself by producing viable offspring. This is supported by reproduction being a commonly selected assessment endpoint in ERAs, often expressed as “a viable reproducing population.”

Additionally, reproduction is frequently the sublethal endpoint of choice in chronic toxicity tests. An underlying assumption of the field-truthing effort at WBG was that if reproductive impacts were observed at the burning pad sites, and if the only apparent difference between the burning pad sites and the reference sites were chemical contamination at the former, then the impacts were due to soil contamination at the burning pad.

Although sampling either males or females will provide valuable information on the reproductive health of rodents at the test sites, only adult male rodents were examined. In general, male reproductive systems are not as complex as female reproductive systems. The complexity of female hormone cycles, the age of the female, sexual activity, pregnancy, and lactation will all increase the variability of responses to chemical exposure. Therefore, due to the uncertainty associated with female reproduction, only males were chosen for our study. However, population metric information (e.g., sex ratio and age distribution), taken for all captured animals, served as an additional line in the weight-of-evidence for use in the overall biological field-truthing conclusions.

Authors, such as Chapin et al. (1997), indicate that sperm parameters are appropriate measures to use for addressing chemical exposures in rodents because they evaluate reproductive success. Sperm parameters are usually expressed by: sperm count (the number of sperm per gram of epididymis), sperm motility (the percentage of forward-swimming sperm in a sample), and sperm abnormality (also termed morphology; the percentage of misshapen sperm in a sample). The underlying hypothesis for WBG was that if maximally exposed terrestrial receptors (e.g., mice and voles with small home ranges) did not display impaired sperm parameters when compared with their counterparts at matched reference locations, then no terrestrial receptors at WBG are being reproductively impaired. Conversely, if the WBG small rodents *did* display significantly impaired sperm metrics, the conservative interpretation of such a finding would be that all other WBG birds and mammals were reproductively impaired.

7.2 LITERATURE REVIEW OF REPRODUCTIVE AND OTHER EFFECTS FROM CHEMICALS

7.2.1 Reproductive Parameters

Reproductive parameters, such as count, motility, and morphology of the sperm, are all reproductive endpoints that have been used in the published literature to evaluate fertility effects or reproductive toxicity (Table 7-2). These measurements can be used as biomarkers of male reproductive effects to aid in understanding toxicological or pharmaceutical testing (Perreault and Cancel 2001, Chapin et al. 1997).

Count, the number of sperm in a measured volume, is the least sensitive of the three sperm parameters (personal communication, Jim Blank, Kent State University). Rodents are robustly fertile and tend to produce more sperm than necessary to ensure fertilization (Meistrich et al. 1994), and a large reduction in sperm count or quality of sperm is required to render a rat infertile (Perrault and Cancel 2001). However, sperm count is linearly related to fertility and sperm count correlates with fertility strongly; a reduction of about 20% in count causes reduced fertility (Chapin et al. 1997). Within a population, small reductions in the sperm count still might be translated into fewer offspring, which could reduce the population overall.

Sperm motility, or movement, is slightly more sensitive than count as a biomarker of fertility. Fertility is reduced if <37% of the sperm are not motile (Chapin et al. 1997). There also appears to be a significant positive relationship between sperm count and sperm motility on the number of pups produced in fertility trials (Chapin et al. 1997).

The most sensitive reproductive parameter is sperm morphology (i.e., the shape of the sperm). Sperm morphology is extremely constant in rats, and even a very small change can be easily detected. This makes it easier for the scientist to distinguish changes caused by a toxicological compound (Perrault and Cancel 2001). Irregular morphology has little adverse effect on fertility until a threshold of approximately >15% observed abnormalities is reached (Chapin et al. 1997), although morphological abnormalities <2% can be detected and can compromise fertility (Perrault and Cancel 2001).

7.2.2 Effects of Explosives and Metals

Explosives (e.g., TNT, RDX, HMX, and DNB) and heavy metals (e.g., aluminum, cadmium, lead, and zinc) can interrupt reproductive endpoints, and they are found at elevated concentrations in the WBG. Therefore, it was decided to further investigate these chemicals of concern using reproductive parameters, such as count, motility, and morphology of the sperm, to help make an informed toxicological-effects decision.

Explosives

2,4,6-TNT can produce negative reproductive effects on mammals. Levine et al. (1984) and Dilley et al. (1982b) found during rodent feeding studies that sperm count was lowered at concentrations of 8 parts per million (ppm), although it was a physiological trend and not statistically significant. At concentrations of 300 ppm, the testes became deformed and atrophied. When sperm were exposed to TNT doses in the range from 0.05 to 3.0 ppm in vitro, the morphology of sperm became altered (Levine et al. 1984).

There are other negative physiological effects when animals are exposed to TNT. TNT altered deoxyribonucleic acid (DNA) of the liver (Lachance et al. 1999). Dilley et al. (1982a, 1982b) observed rough fur when lower concentration doses of 0.125%:d for 13 weeks were fed in the laboratory. In addition to the rough fur, both they and Levine et al. (1984) observed organs to be enlarged and lesions to appear when medium (125 ppm) to high (range of 188 to 193 ppm) concentrations were fed.

RDX produces negative reproductive effects in laboratory rodents when they are exposed to concentrations between 8.3 ppm and 100 ppm during feeding studies. Sperm count was lowered at concentrations of 8.3 ppm, but it was not statistically significant (Dilley et al. 1982b). However, Dilley et al. (1982b) also found that sperm motility was not reduced when concentrations ranged between 8.3 ppm and 100 ppm. Levine et al. (1984) found sperm morphology impacts at concentrations of 1.0 ppm in vitro. Differences in the uptake of the compound from the food versus direct in vitro exposure likely explain these discrepancies. Other noticeable reproductive effects occurred when rodents were exposed to RDX; for example, testes weight decreased when 0.05% ppm per day was fed (Dilley et al 1982b). Dilley et al. (1982b) found that testes became atrophied at 300 ppm. He also noted that if TNT and RDX were combined, these same effects could be noted at 150 ppm, instead of 300 ppm.

Additional physiological effects have been cited when animals are exposed to RDX. The liver showed DNA alterations when exposed to 0.01% RDX concentrations in vitro (Lachance et al. 1999). Dilley et al. (1982a) found lesions on the liver and spleen when animals were exposed to RDX. Dilley et al (1982a) also found both the spleen and the liver became enlarged when concentrations of 125 ppm were fed. However, Levine et al. (1984) did not observe any enlargement until 300 ppm was fed. Both Dilley et al. (1982b) and Levine et al. (1984) observed rough fur at low concentrations (<0.01%) in their laboratory animals.

Other explosives such as 1,3-dinitrobenzene (m-DMB) and HMX also show effects when animals are exposed. When animals were fed concentrations greater than 3 ppm of m-DMB, testes weight, sperm

motility, and overall body weight decreased (Linder et al. 1986). Lachance et al. (1999) found HMX to alter the DNA of the liver, blood, and other organs when it was exposed in vitro.

Metals

Metals, such as lead (Pb), show effects when concentrations are fed daily in the range from 0.25%:d to 0.50%:d. Sperm count was reduced at lower (<0.25%) food dose concentrations (Wadi and Ahmad, 1994). However, another study (Zhang et al. 1993) did not show an effect until 10,000 ppm. Both studies found sperm motility to be reduced at medium (<3162 ppm) food doses (Zhang et al. 1993) and at higher (0.5% concentration) doses (Wadi and Ahmad 1994). Wadi and Ahmad (1994) also observed alterations and abnormalities in the morphology of the sperm at high concentrations (0.5%). Ma (1989) observed a decrease in overall body weights of some rodents (wood mice) but not of all captured species (shrews and voles) when they were captured on an old shooting range. He also captured shrews and voles that showed a significantly increased kidney-to-body weight ratio, which is indicative of lead poisoning. At another location, Ma et al. (1991) also captured shrews indicating toxic exposure at 25 ppm in their liver and kidneys, which is the critical renal Pb level for small mammals.

Aluminum is another metal that shows effects on small mammals when concentrations range from 24 to 200 ppm. Sperm count was reduced when 27.4 ppm was fed, and all sperm died when 200 ppm was fed (Llobet et al. 1995). Llobet et al. (1995) also found that motility was unaffected until animals were fed doses up to 100 ppm. However, he concluded that when animals were fed over 50 ppm of the metal, testes weight and overall body weight always showed a decrease.

Additional heavy metals were also found to have an effect on animals. Pascoe et al. (1996) found that both arsenic (As) and zinc (Zn) reduced body weights and enlarged the liver when wild mammal species were captured on sites that had been contaminated from mining wastes. Ma (1989) concluded that cadmium (Cd) caused renal failure when intake levels exceeded 120 ppm in small mammals. Cadmium was also found to reduce body weights and enlarge both the liver and the spleen when animals were living at sites where soils and/or sediments showed levels of contamination (Pascoe et al. 1996, Ma et al. 1991).

7.3 FIELD SAMPLING METHODS

For small mammal sampling, the same six study sites used for vegetation sampling (three burning pad pairs and three reference pairs) were included in the May through June 2000 sampling event. Trapping and subsequent sampling were performed using Sherman live traps during two events. The first trapping event took place from May 17 through 20 at the WBG sites and from May 21 through 24 at the reference sites. The second trapping event took place from June 13 through 15 at WBG sites and from June 17 through 19 at the reference sites. The time separation between the two trapping events resulted from an attempt to avoid unseasonably heavy rains that began in mid-May. The rainstorms caused flooding across much of the trapping area on both the burning pad and reference sites. Therefore, small mammal trapping ceased until the weather became more advantageous for trapping.

7.3.1 Study Sites

The rationale behind the selection of burning pads at WBG and at the reference locations was discussed earlier in Sections 4.2 and 4.3. For example, soil types from previously conducted surveys were examined to ensure that the reference and burning pad sites were agronomically similar.

The configuration and size of the study sites were based on the home ranges of the target species, meadow voles (*Microtus pennsylvanicus*) and white-footed mice (*Peromyscus leucopus*). The typical home range of a meadow vole is 0.04 to 0.4 ha (0.1 to 1 acre), whereas the white-footed mouse generally has a home range of 0.2 to 0.6 ha (0.5 to 1.5 acres) [Burt and Grossenheider 1980]. To provide for both home range sizes, a circular home range with a diameter of at least 88 m (289 ft) was assumed for any given pad. This home range size presented a concern at WBG, however, because it overlapped considerably into nearby pads. To compensate for this overlap, a 50-m (165-ft) radius was measured from the center of each pad; therefore, only slight overlapping between the adjoining pads was present (Figure 7.1).

7.3.2 Trapping Procedures

The goal was to trap 27 adult male white-footed mice and 27 adult male meadow voles from each of the six study sites for sperm analysis and wet liver weight measurements. Trapping was performed using Sherman live traps for 8 days (4 days at WBG and 4 days at reference sites) in May and for 6 days (3 days at WBG and 3 days at reference sites) in June as indicated above. Traps were left out for an extra day in May to compensate for a heavy rainfall event. One hundred and fifty traps were placed at each of the three WBG sites and checked daily for 3 to 4 days. Upon completion of trapping at the WBG sites, the traps were checked, removed, and then placed at the three reference sites for 3 to 4 days. All traps were placed selectively (i.e., in preferable habitat) in each study site to maximize trapping success.

Bait and cottonballs were placed into each Sherman live trap and replenished when necessary. Cottonballs provided nesting material for the rodents until researchers arrived the next morning. Initially, a peanut butter and oatmeal mixture was used as bait. After May 18, the bait was changed to a horse sweet feed mix for two reasons: (1) ants were attracted to the peanut butter mixture and may have acted as a deterrent to rodents going into traps; and (2) vole and mouse feces were found at the entrance and on top of the traps, suggesting that the bait was not enticing enough for the rodents to investigate further. Large Tomahawk traps were placed in various areas at each site to minimize disturbance of the Sherman traps by raccoons. Tomahawk traps were baited with sweet feed mix, Squirrel Delight mix (i.e., peanuts, corn, and sunflower seeds), and marshmallows. All trapped raccoons were released daily.

On each first day of sampling, Sherman live traps were numbered and set during the mid-afternoon. Traps were then checked between 8:00 a.m. and 9:00 a.m. the following day. If occupied, the trap was held downwind at arm's length and confirmation of the trap's content was made. Each live animal was placed into a plastic bag and identified to species, aged, sexed, and weighed with a Pesola scale. If the rodent was a target species, it was put into a clean trap and placed into a cooler for transport to the on-site laboratory. Most non-target animals were marked with nail polish for recapture identification and released. Squirrels, chipmunks, and rabbits were not marked with nail polish due to the difficulty in handling these species. Replacement traps were placed in the original location, baited, and set. The GPS was used to map target species trap locations for the purpose of co-locating these data with data from other field measurements (e.g., soil). GPS coordinates are Ohio State Plane, North American Datum 83.

7.3.3 Reproductive Measurements

Sperm Analysis Procedure

All trapped adult male target animals were euthanized by carbon dioxide inhalation after transport to the on-site laboratory. Individual animals were placed into a chamber connected to a CO_2 tank. Following euthanasia, the animal was weighed and the right epididymis was surgically removed, minimizing blood contamination. The excised tissue was placed immediately in a pre-warmed suspension medium containing Phosphate Buffered Saline with 1% Bovine Serum Albumin. A 3-minute "swim out" period was used to allow sufficient time for the sperm to enter the medium. A 100-µm-deep cannula was then

inserted into the medium and a sample obtained. The cannula was then inserted into the retractable stage of a Hamilton-Thorne Integrated Visual Optics System (IVOS) Sperm Analyzer (described below). A general examination of the sperm sample was made on the computer monitor. The analyzer was preset to automatically move the stage to five different fields along the length of the cannula and to store each motion image on the optical disk. Each image was then analyzed by the IVOS and percent sperm motility was calculated. The images were uniquely identified by study number, animal number, and field number. The left epididymis was frozen on dry ice and transported to the laboratory for subsequent determination of caudal epididymal sperm count. Wet liver weight was recorded for each subject.

Sperm Motility, Total Sperm Count, and Sperm Morphology Determinations

A Hamilton-Thorne IVOS Sperm Analyzer located at the on-site field laboratory was used to measure adult male reproductive parameters. The main unit of the IVOS analyzer contains an internally housed microscope, a retractable stage, and an on-board computer system to perform the analyses. A color monitor was utilized to review the sample quality. The motion images were automatically saved to a Hewlett Packard write-once optical disk drive creating a permanent record for precise image reproduction and retrieval. As part of the extensive method development program, the cell characteristics (size, shape) unique to sperm were established, and the parameters were added to the IVOS computer "set-up" program. This program allowed the IVOS to not only distinguish sperm cells from surrounding blood cells and debris, but also to accurately identify motile versus non-motile sperm.

Later, at Pathology Associates International, an SAIC facility in Maryland, each image was recalled from the optical disk and analyzed for motile and non-motile cells. A percent motility for all five recorded fields was determined for each animal. Straight-line, curvilinear and path velocities, progressive motility and cross-beat frequency were also calculated. The total sperm count sample was prepared from the left caudal epididymis, which was obtained at necropsy and frozen on dry ice. The epididymis was thawed and the caudal section removed and weighed in order to report the total sperm count data as millions of sperm/gram of caudal epididymal tissue. The caudal epididymis was then homogenized and a 100-µL sample added to a vial containing a fluorescent dye to stain the DNA in the sperm head. This prevented surrounding debris from being counted as sperm. A 9-µL sample was added to a slide, which was cover-slipped, secured to the retractable stage, and then loaded into the IVOS. The analyzer automatically counted the stained sperm heads for 20 fields per slide. This minimized the sperm cell distribution variance within single samples. The analyzer then calculated the total number of sperm per gram of caudal epididymis. For all animals analyzed for epididymal sperm count, two sperm morphology slides were prepared from the epididymis sample prior to homogenization. These slides were transported to Pathology Associates International, stained with 5% Eosin, and cover-slipped. For each animal, 200 sperm cells were microscopically evaluated for head and tail abnormalities. Each sperm cell was examined for proper size, shape, and for double heads and/or tails. The sperm morphology data were represented as the percentage of abnormal sperm with regard to the 200 counted.

7.4 WEIGHT-OF-EVIDENCE APPROACH

Weight-of-evidence is used to compare WBG findings with reference site findings and/or thresholds from the literature. There is no statistical analysis of the sperm data because of the small sample size. A weight-of-evidence approach evaluates multiple lines of evidence. This method identifies probable causes of observed ecological responses, using arguments derived from human epidemiology. In this approach, a causal relationship between a stressor and a response is proposed. Then a series of questions, or criteria, is applied to the proposition. Not all criteria need be satisfied to demonstrate that the proposition is likely true, but weight is added to the conclusion by each criterion that is satisfied in the proposition(s). Ultimately, professional judgment is used to establish the strength of the causal relationship. The

weight-of-evidence approach is especially useful when: (1) there are insufficient data for robust statistical analyses, (2) toxicity or other criteria are uncertain, or (3) exposure models are not sufficiently precise for statistical hypothesis testing.

The criteria in the weight-of-evidence approach are as follows:

- Temporal association—did the supposed causes precede measurable effects?
- Spatial association—is the affected population exposed to the proposed causative agent?
- Stressor response—does the severity of the effect vary in response to the magnitude of exposure to the proposed causative agent?
- Strength of association—are there other potential causes that could be present or act antagonistically/synergistically to produce the observed effect?
- Plausibility—does the proposition make sense and is it consistent with known etiological and scientific principles? Is there a reasonable mechanism of action?

Each of these criteria is further explained below.

Temporal associations rely on measures of biological populations or physical media being made before and after an event. If measurements were not made before the proposed cause, as is often the case, there may be no direct evidence for temporal association. Correlated fluctuations in the proposed stressors and the effect can provide evidence for both temporal association and quantitative stressor response.

Spatial association may be demonstrated by a decrease in the severity of effect in the indicator organisms with distance from the proposed causative agent. It may also be shown by a distribution of effects in relation to contaminant transport, such as location in the surface soil of a hot spot, in a groundwater plume, or downwind from an airborne source. Chemical transport models may describe the spatial association in quantitative or qualitative terms. Spatial association can also be demonstrated through comparisons of stressed situations relative to an unstressed reference situation.

A positive correlation between the magnitudes of the stress and the response is strong evidence for causality. If a contaminant can be measured in the exposure media, then it can be quantitatively compared to the severity of observable or measurable effects. Ecological effects measurements are useful in establishing stressor/response relationships. Otherwise, indirect measures of the effect may be made, including expected attenuation with distance from the proposed source.

Demonstrating strength of association requires an adequate database and application of good scientific judgment. Confounding factors must be taken into account when evaluating the strength of association. For example, several contaminants may be released into exposure media, and a population may respond simultaneously to more than one of them. The presence of an antagonist may mask the effects of a stressor, weakening the apparent temporal associations between stressor and effect.

Scenarios by which the stressor causes the observed response must be plausible. Scientifically sound principles, preferably backed by experimental evidence or other field observations, must be used in evaluating the plausibility of the proposition.

Criteria within the lines of evidence are evaluated quantitatively or qualitatively, depending on the types and quality of data available. Thus, a gradient of effects in indicator organisms associated with

assessment and measurement endpoints with distance from the proposed source may be used as evidence for spatial association, whereas evaluation of a temporal association may be based on circumstantial evidence rather than on data obtained directly before and after the event. Experimental evidence may also be used to evaluate these and other weight-of-evidence criteria. But, the practical sense of weight-of-evidence methods consists of lists of pro and con topics based on the above themes.

7.5 RESULTS

Both field and laboratory results are provided below.

7.5.1 Overview of Field Results

A total of 152 individuals were captured from the WBG sites and the reference sites combined (Table 7-3). Fifty-six animals were trapped at the WBG, and 96 animals were trapped at the reference sites. Eighty-eight adults, sub-adults, and juveniles of the target species were captured (Table 7-4). There were 24 adult females, 17 sub-adults, and 25 juveniles of the two target species captured at all sites. Of this total, 19 animals were retained for reproductive analysis via rodent sperm analysis (RSA) [Table 7-5]. Fourteen of the 19 target species were white-footed mice (six individuals from WBG sites and eight from the reference sites), and the remaining five animals were meadow voles (four individuals collected from WBG and one from the reference sites). Appendices C and D (SAIC 2001) provide the details for the above information.

7.5.2 Species Composition

Six small mammal species were captured at WBG (Table 7-3). These included the white-footed mouse, meadow vole, eastern cottontail rabbit, deer mouse, masked shrew, and woodland jumping mouse.

Eight small mammal species were trapped at the reference sites (Table 7-3). These included the white-footed mouse, meadow vole, eastern cottontail rabbit, short-tailed shrew, eastern chipmunk, meadow jumping mouse, Southern flying squirrel, and woodland vole.

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7.5.3 Reproductive Status of Males and Females from Field Observations

Six adult male white-footed mice captured at WBG sites and eight adult male white-footed mice captured from the reference sites were submitted for RSA.

A total of 12 white-footed mice captured at the reference sites were identified in the field as being adult and sub-adult females. Of the adult females, two were pregnant (17%) and four (33%) were lactating. Eight white-footed mice captured at the WBG sites were identified in the field as being adult and sub-adult females. Of the adult females, one (13%) was pregnant and three (38%) were lactating. These percentages between the WBG sites and the reference sites are similar.

7.5.4 Reproductive Measures of Males from On-site Laboratory Observations

The SAP calls for pair-wise statistical comparisons between paired contaminated sites and reference sites for each biological measure. A minimum of two target animals is necessary for calculating the variability

of each group to be compared, and five or more animals would be preferred to obtain a reasonable estimate of variability. The number of target animals sampled for each species at each sample location was not adequate for conducting statistical tests for paired sites. Therefore, no statistical techniques were applied.

For the meadow vole, pads 58 and 59 were the only locations where more than one target animal was sampled. Only one meadow vole was collected across all of the reference sites. Therefore, a statistical comparison between results from the contaminated sites and reference sites is not possible for the meadow vole data.

For the white-footed mouse, 1 to 4 animals were sampled at each study site (WBG and reference) with a total of 14 animals (Table 7-5). Although eight target animals were collected in the contaminated site, weight (whole body and liver) measurements could not be made for one animal because of equipment problems. Six results were obtained for sperm count, but only five results for the other biological attributes. The number of measurements is not sufficient to statistically evaluate differences site by site, as explained above. Detailed data are found in Appendices D and E (SAIC 2001).

For all WBG animals, sperm count averaged 1409×10^6 sperm/g tissue (Table 7-6). Sperm motility (percent) averaged 99.2, while mean abnormal sperm morphology was at 0.3% for the white-footed mouse and 0.1% for the meadow vole. None of the measured values at WBG came close to any threshold from the literature (Table 7-2). For example, sperm count needs to show a reduction of 80% before reproductive success is compromised. The reduction in sperm motility is 40% to compromise reproductive success. The rate of abnormal sperm morphology must exceed 4% in order to affect reproductive success. In each case, the observed values do not come close to the thresholds. Sperm metrics from the reference sites are similar and differ only by a small amount (Table 7-6). Therefore, the rodents examined at WBG have normal reproductive capacity.

7.6 WEIGHT-OF-EVIDENCE CONSIDERATIONS

Because small mammal trapping results produced limited data, statistical analyses were not applied to these data. The logical approach, considering the nature of the weight-of-evidence information, was to make comparisons between the data for the six pads and the data for the reference sites. This is complicated however, as the types of chemical contamination differed between the pad pairs. Although statistical tests for the attributes were not applied, the direction of the observed physiological differences can be examined to see if they are consistent with the conceptual model of the site (i.e., the greater the contamination at a pad, the greater the ecological effects as measured in small mammals). Conclusions concerning the ecological status of the small mammals at the WBG sites are presented as propositions, which are followed by the supporting evidence. After the propositions and evidence are presented, there is a discussion and uncertainties section followed by conclusions and summary.

Propositions one, two, and three address physiological effects that occur within the bodies of the small mammals, individual reproductive capacity, sperm parameters, and liver and body weight. Propositions four, five, and six concern issues at the population and community levels that are external to individual small mammals—evidence of exposure to chemical contaminants, reproductive success, and structure and function of the small mammal community. Proposition seven discusses the results of the HQ re-screen.

Proposition One: The chemical contamination at WBG did not adversely affect individual reproductive capacity in the captured male mammals.

- Observed sperm count was much higher than the 80% published threshold of reproductive effect. There was insufficient reduction in order to see an adverse reproductive effect.

- Sperm motility was much higher than any published threshold of reproductive effect (40 to 50%). Thus, there is insufficient reduction in sperm motility to see an adverse reproductive effect. Sperm motility was slightly (*i.e.,* < 1%) higher at the contaminated sites than at the reference sites. The direction of this difference is opposite the expected direction of contamination-impaired sperm motility, and the difference is very small.

- The number of abnormal sperm collected from rodents captured on the site was not sufficiently above (i.e., greater than 4%) the incidence of abnormal sperm collected from rodents captured on the reference site to indicate reproductive effect.

All the male reproductive parameters measured are within the acceptable limits for reproduction as indicated by the available scientific literature

Proposition Two: The chemical contamination at WBG adversely affected sperm parameters in the captured mammals, although not to the degree that reproductive capacity was affected.

- Sperm count was 16.7 % lower at the contaminated sites than at the reference sites. This difference is in the direction expected of contamination-impaired sperm production.

- Abnormal sperm morphology was 0.3% for white-footed mice and 0.1% for meadow voles at contaminated sites versus 0.0% at reference sites for both mammals. This difference is in the direction expected of contamination-impaired sperm morphology.

For the captured animals, the small adverse sperm parameters observed compared to the reference sites are not expected to translate into adverse reproductive effects.

Proposition Three: The chemical contamination at WBG may have had an effect on physiological parameters, such as liver and body weight.

- Liver-to-body weight ratio was 9% higher at the contaminated sites than at the reference sites. The direction of this difference is consistent with an enlarged liver for processing toxic materials at the contaminated sites.

- Animal body weight was, on average, 10% higher at the contaminated sites than at the reference sites. The direction of this difference is not consistent with inhibited growth expected at the contaminated sites.

Proposition Four: Although chemical contamination at WBG pads appeared to be affecting some physiological attributes, there is some evidence suggesting it did not negatively influence reproduction of the small mammals.

- There were nine (Table C.1 in April 2001 report) pregnant and lactating females of various small mammal species trapped on/near the burning pads.

- There were all age groups of small mammals represented, e.g., juveniles, sub-adults, and adults.

Proposition Five: Chemical contamination at WBG pads does not appear to be affecting some aspects of the small mammal community structure and function.

- Fifty-seven small mammal individuals were captured at the pads and 96 individuals at the reference sites. These were comprised of eleven different species (white-footed mouse, meadow vole, Eastern cottontail rabbit, deer mouse, masked shrew, short-tailed shrew, Eastern chipmunk, meadow jumping mouse, woodland jumping mouse, Southern flying squirrel, and woodland vole). Species richness, or the number of species, was nearly equal between pads and reference sites (including species, e.g., masked shrew and woodland vole, which occurred as incidentals).

- Small mammals of various species were present, e.g., six different small mammal species were captured at the pads. (from above, delete this bulleted item if the information in the above bullet is the same, it appears to be the same)

Proposition Six: Chemical contamination at WBG pads may be affecting some aspects of the small mammal community structure and function.

- Seventeen shrews were captured at the three reference sites, but 0 shrews were captured at contaminated pads.

- Chipmunks were captured at all three reference sites, but no chipmunks were captured at the pads.

- The number of captured individuals (abundance) at the contaminated sites was approximately half the number captured at the reference site.

Proposition Seven: HQs indicate that chemical contamination at WBG have mixed results with respect to contamination having adverse effects on small mammal species.

- All pads had metals and RDX with the hazard quotient below one for the mouse.

- Whereas, for the shrew, HQs exceeded 1 based on the maximum concentration for arsenic at all site pad pairs. Additionally, all pad pairs had either Sb, As, Cd, Hg with HQs that exceeded 1 for the shrew. Specifically, 37/38 had an HQ > 1 for cadmium; pads 58/59 had an HQ of antimony and mercury > 1; and pads 66/67 had an HQ for antimony > 1. Further, pads 66/67 had RDX with an HQ >100 for the shrew.

7.7 DISCUSSION AND UNCERTAINTIES

Spatial heterogeneity of soil contamination at WBG creates variation in the degree of small mammal exposure and, consequently, in possible small mammal effects. For example, soil concentrations of a given contaminant (2,4,6-trinitrotoluene) were found to range from 2.3 to 2,000 mg/kg among eight samples on Pad 67 within a 5-m radius of vegetation plot 132 (see Sect. 5.4). The home ranges of the two target species (white-footed mouse and meadow vole) are reported to be up to 1.5 acre and 1 acre in size, respectively (Burt and Grossenheider 1980). An uneven distribution of contaminant concentrations within the 165-ft radius trapping area (1.96 acre) around each pad [3.92 acres per each of the paired pads minus the slight overlap (see Fig. 6-1)] could easily result in the uneven exposure of individual and small populations of small mammals to contaminants. Intra-specific competition, as expressed by actual territories of individual small mammals, could tend to exclude individuals from certain areas and restrict them to other areas. Varying contaminant exposures could result in intra-specific variations of exposure effects from this behavioral factor.

Home ranges of small mammals are larger than any one burning pad, so that exposure may be only a portion of what it potentially could be. Individual pads range in size from 305 to 660 m^2 or 0.08 acre to 0.16 acre; home ranges of the two target species (white-footed mouse and meadow vole) are up to 1.5 acre and 1 acre, respectively. Home ranges also contract and expand as a function of seasonal and other conditions. Roughly 4-acre areas were trapped around each pair of pads. The low trapping success reflects, in part, probable low population densities and, therefore, probably larger-than-expected home ranges.

Possible microhabitat of food supply differences existed between sites and reference pads, despite careful selection of reference sites. The reference location selection process screened 20 potential reference sites. Selection was based on structure (e.g., grass field bordered by trees) rather than species composition (e.g., field of predominantly bluegrass bordered by oaks and hickories). Subtle differences in soil conditions (e.g., compaction) could influence the numbers of soil-dwelling invertebrates. This, in turn, affects food availability. Such potential differences in habitat could result in slightly different small mammal community composition and population densities.

Weather conditions surely influenced the trapping success of small mammals, resulting in low numbers that could not be compensated for by statistical treatment. For example, heavy rains interrupted the sampling schedule and caused a delay of about three weeks. Generally, light rain encourages small mammal activity, while heavy rain discourages activity (Getz 1989). Heavy rains occurred during part of the trapping sessions. Trap type (i.e., Sherman live traps) was chosen for the desired species for the laboratory reproduction studies, but it is not the preferred trap type (pitfall traps) for shrews. Different trap types would reduce trapping effectiveness for certain species (Gerard and Feldhamer 1990; Feldhamer 1993; Shore et. al 1995).

Some differences in number per species can be explained by non-chemical parameters. These parameters included food (chipmunks near nut trees), weather (more shrews trapped in light rain), and physical conditions (no short-tailed shrew near compacted soil). Lack of shrews at WBG could also be explained by chemical poisoning, either by contaminant uptake in food or lack of food because of toxicity to the food.

Extrapolating results to an entire population is associated with some restraint because reproductive effects, i.e., sperm metrics, were studied in males only, and laboratory measurements of female reproduction were more appropriate to a laboratory setting than to the field. Measurements of female reproductive systems were excluded based on their greater complexity, higher variability of responses to chemicals, and the more expensive and demanding measurement logistics. A sample size of 27 samples from each burn pad and reference location ($27 \times 6 = 162$ individuals total) was calculated as necessary to meet the desired statistical criteria. The small sample size (14 total white-footed mice and 5 meadow voles across all paired pads and reference sites) resulted in further statistical limitations.

As noted earlier, liver weight was higher at the contaminated sites than at the reference sites. This difference fits the conceptual model of the effects of contamination on small mammals. If true differences in the biological attributes did exist between the populations of white-footed mice in the reference and contaminated sites, based on the limited data, it can be estimated that these differences are less than 30% for body and liver weight measures. The results of these tests suggest that the contamination at WBG may have more effect on liver weight than on reproductive attributes. Despite rodents at burning pads having heavier livers (i.e., a biomarker of exposure to contaminants), reproductive measurements of sperm count, motility, and morphology were far below published ecologically significant thresholds.

Chemicals may have multiple effects on mammals, not just effects on their reproductive systems. Nearly all HQs greater than 1.0 for the burning pads of interest were derived from toxicity reference values with a reproductive endpoint (e.g., TNT, RDX, and Pb). Other HQ-based exposure effects are reduced body weights and enlarged livers (As and Zn); liver, blood, and other organs altered (HMX); and renal failure at high exposure levels (Cd) (Levine et al. 1984, Hendricks et al. 1995, Chasen et al. 1997, Zhang et al. 1993, Ma et al. 1989, Wadi et al. 1999, Meistrich et al. 1996, Pascoe et al. 1996).

Although some hazard quotients at WBG were higher than the regulatory threshold of 1, weight of evidence (field investigations and revised HQ values) suggests no to little ecological effect. In the specific case of small mammal reproduction, there was much evidence (see above propositions and evidences) that small mammals were indeed capable of and were actually reproducing successfully on/around the chemically contaminated pads.

7.8 CONCLUSIONS AND SUMMARY

The biological field-truthing effort at WBG included carefully designed field measurements, weight-of-evidence analysis, and a discussion and uncertainties section. Using the limited sampling results of this study and professional judgment, the following conclusions and summary concerning small mammals may be drawn from these efforts:

1) The weight of evidence suggests that white-footed mice and meadow voles are capable of and were reproducing successfully on and around chemically contaminated areas of the WBG. This is based on both the community of small mammals observed, including lactating females, and the comparison of male reproductive parameters to published threshold values.

2) The chemical contamination at WBG may have had an effect on some physiological parameters, such as liver and body weight. However, liver and body weight effects may not be directly linked to toxicity, as information on the specific nature of the injury requires precision before their consequences can be assessed [Casarett, L.J., Doull, J. Toxicology. The Basic Science of Poisons Fourth Edition (Chapter 10). Macmillan Publishing Co., Inc. 1991.]

3) There was evidence of community structure at both the pads and reference sites.

4) Re-screening of HQs for small mammals indicates much lower risk than the original screen. Although there are HQ values that exceed 1, generally, the HQ values do not represent a high level of concern.

5) Although there appeared to be a reduced numbers of individuals trapped on the contaminated areas, including a lack of shrews on the burning pads, these results are possibly due to the limited amount of data that was collected and the specific trapping methods employed in the study.

Based on the evidence above, it does not appear that the chemical contaminants are impacting the small mammals within the WBG to a level that might require extensive remediation or intervention.

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FIGURES

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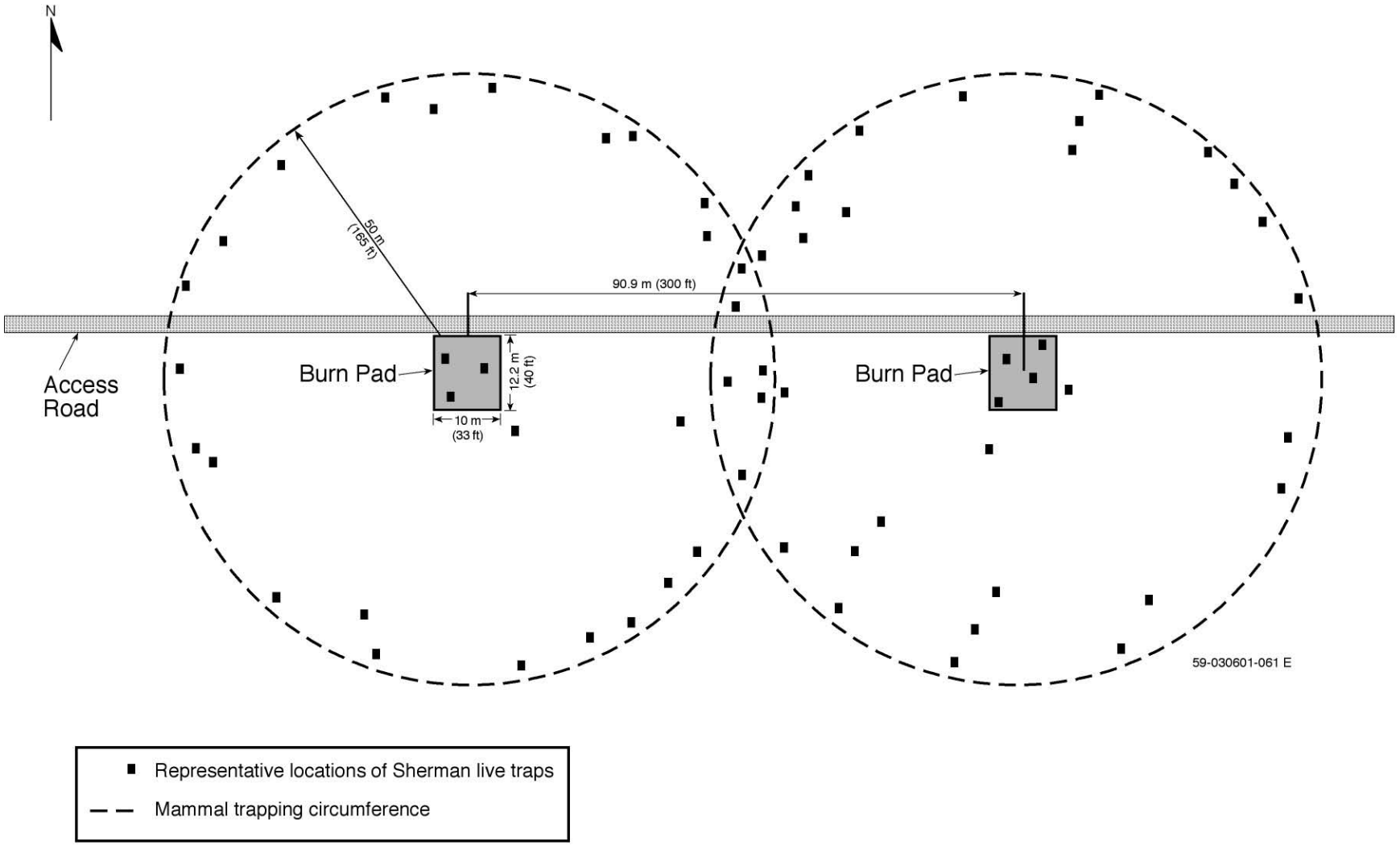

Figure 7-1. Burning Pad Pair at WBG with representative small mammal trapping locations.

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TABLES

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Table 7-1. Summary of Potential Methods for Assessing Impacts to Small Mammals at WBG, RVAAP, Ohio

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
Small Mammal Population Analytical Measures									
1	Prevalence or abundance	List of species observed and number of each species	The higher number of taxa the better	Fundamental ecological measure; need to obtain estimate of what organisms are present and how many	Probably 1 to 2 weeks of trapping	Applicable to all potential habitats where small mammals are expected to be present	Probability high	Davis and Winstead (1980)	Not recommended for protocol because small mammals too hard to see during visual census
2	Sex ratios	Can be expressed as "number of adult females per adult male," or "X% females"	Optimal is approximately equal males and females	Fundamental ecological measurement; used to evaluate whether it is within range needed for normal reproductive performance	Probably 1 to 2 weeks of trapping	Applicable to all potential habitats where small mammals are expected to be present	Probability high; trapping bias?	Downing (1980)	Not recommended for protocol unless linked to rodent sperm analysis
3	Age ratios	Can be expressed as "number of individuals in each age class" or "X% of each age class"	Prevalence of young classes = growing population; prevalence of older classes = dwindling population	Fundamental ecological measurement; used to interpret age-specific reproductive rates and is a measure of the natality and rearing success of the population	Probably several weeks of trapping	Need sufficiently large sample population to get good estimates of distribution	High, especially in short-term study	Downing (1980)	Not recommended for protocol because some species have such short durations from birth to reproductive age unless linked to rodent sperm analysis
4	Natality and rearing success	Estimates of the number of young per adult female (natality) and recruits (young that survive to next season) per adult female (rearing success)	Generally, the higher the better, but should be in equilibrium with mortality	These are good indicators of population health and suggest how much mortality a population can withstand without a decline; also indicates maximum rate at which a population can rebound following decimation	Requires repeated field sampling (couple of weeks each session) over at least two seasons	Applicable to all potential habitats where small mammals are expected to be present	High, especially in short-term study	Downing (1980)	Not recommended for protocol because study duration too long

Table 7-1. Summary of Potential Methods for Assessing Impacts to Small Mammals at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
5	Mortality and survival	Survival rate of adults (proportion alive after specific time period)	Generally, the lower the better, but should be in equilibrium with natality	Fundamental ecological measurement; mortality decreases the population	Requires repeated field sampling for at least a couple of weeks by one of various methods such as mark-recapture, catch-effort, etc.	Applicable to all potential habitats where small mammals are expected to be present	High, especially in short-term study	Downing (1980)	Not recommended for protocol because study duration too long
6	Population density	Number of individuals per certain area	Higher the better, up to limit of carrying capacity	Fundamental ecological measurement; populations tend towards carrying capacity of the habitat	Probably 1 to 2 weeks trapping; need population and sample area estimates	Applicable to all potential habitats where small mammals are expected to be present	CVs range from 8.1% to 47%	Davis and Winstead (1980)	Recommended as one of the methods for the protocol
Diversity Measures (Community)									
7	Species counts	Number of species per unit area	More species the better	Species diversity is one of the most important aspects of community structure; this is the simplest measure of diversity	Fairly low effort (few days)	Applicable to all potential habitats where small mammals are expected to be present	Probability high	Hair (1980)	Has two main draw-backs: (1) unweighted and fails to account for relative abundances, (2) depends on sample size; not recommended for the protocol
8	Simpson's Index	Probability that two individuals selected at random from a community of N individuals are from the same species	Greater the index, the better	Species diversity is one of the most important aspects of community structure	May need few days to couple weeks of sampling	Applicable to all potential habitats where small mammals are expected to be present; appropriate when for relative degree of dominance of a few species is needed rather than overall evenness of all species.	Probability high	Hair (1980)	Sensitive to the abundances of the 1 or 2 most common species in the community; not recommended for the protocol

Table 7-1. Summary of Potential Methods for Assessing Impacts to Small Mammals at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
9	Brillouin's Formula (H)	Probability that two individuals selected at random from a community of N individuals are from the same species	Greater the index, the better	Species diversity is one of the most important aspects of community structure; this method measure absolute diversity	Probably more intensive than other diversity indices because all individuals in community need to be counted	Applicable to all potential habitats where small mammals are expected to be present; appropriate when all individuals in the community can likely be counted	Probability high	Hair (1980)	Requires all individuals in the community to be counted, thus could be long study duration. Not recommended for protocol.
10	Shannon-Wiener Function (H')	Probability that two individuals selected at random from a community of N individuals are from the same species	Greater the index, the better	Species diversity is one of the most important aspects of community structure	May need few days to couple weeks of sampling	Applicable to all potential habitats where small mammals are expected to be present; appropriate when all individuals in the community cannot likely be counted	Probability high	Hair (1980)	Only requires a random sample from community, not all individuals; not recommended for the protocol, though, because of small size of the pad areas and non-diverse habitats
11	Equitability Index	This is the ratio of observed diversity to the maximum possible diversity		This indicates the evenness with which individuals are divided among the species present	Little additional calculation time once the observed diversity index is known	Best where abundant number of individuals expected		Hair (1980)	Limitation is species number; not recommended for the protocol
Small Mammal Biomarkers									
12	Sperm counts, morphology, and motility	Number of spermatozoa/ individual	Greater the numbers, the better	Good indicator of reproductive condition of males	Could take days for field sampling; lab analysis in few hours or days	Anywhere the mammals are present	Probability moderate	Kirkpatrick (1980); Chapin et al. (1997)	Much related research; destructive sampling; recommended for protocol

Table 7-1. Summary of Potential Methods for Assessing Impacts to Small Mammals at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
13	Luteal gland counts	Number of corpora lute/ individual	The more counts, the better	Indicates number of ova shed in females	Moderate for field sampling; lab analysis hours to days	Best where abundant number of individuals expected	Probability high, age-specific	Kirkpatrick (1980)	Destructive sampling; not recommended for protocol
14	Follicle counts	Number of follicles/ individual	The more counts, the better	Ruptured ones give estimate of litter size in females	Could take days for field sampling; lab analysis in hours to few days	Best where abundant number of individuals expected	Probability high, age-specific	Kirkpatrick (1980)	Destructive sampling; not recommended for protocol
15	Fetal counts	Number of fetal counts/ individual	The more counts, the better	Best index of number of young produced per female because little in utter mortality	Could take days for field sampling; lab analysis measured in few hours or days	Best where abundant number of individuals expected	Probability high, age-specific	Kirkpatrick (1980)	Not recommended for protocol
16	Placental scars	Number of scars/ individual	The more counts, the better	Similar information as for fetal counts, but harder to differentiate sets of scars in small mammal females	Could take days for field sampling; lab analysis in few hours or days	Best where abundant number of individuals expected	Probability high, age-specific	N	Destructive sampling; not recommended for protocol
17	Adrenal gland weight	Weight of gland	The lower the weight the better	Most used index of chronic stress; weight increases as stress increases	Could take days for field sampling; lab analysis measured in few hours	Best where abundant number of individuals expected	Probably high	Kirkpatrick (1980)	Not recommended for protocol
18	Cytochrome P-450	Cytochrome P-450 concentration in tissue	The lower the P-450 activity, the better	USGS evaluating it in BEST program for multiple taxa	Lab analysis is fairly quick	Applicable where small mammals are exposed to organic chemicals	Probably high	USGS (1994)	Shows promise as indicator for stress from exposure to organics, but requires sacrificing animals; recommended for protocol
Chemical analyses of mammal and their prey tissues									
19	Inorganics in small mammal tissues	Milligrams (mg) contaminant/ kilograms (kg) tissue	The lower the concentrations, the better	Indicates exposure to and bioaccumulation of inorganic contaminants by small mammals	Collection can take a few days to 1 to 2 weeks; analysis in a few days	Where mammals are present at contaminated soils	Probably high	EPA (1986)	Potentially recommended for protocol to demonstrate exposure

Table 7-1. Summary of Potential Methods for Assessing Impacts to Small Mammals at WBG, RVAAP, Ohio (continued)

Item No.	Method Name	Potential Methods		Selection Criteria				References	
		Output	Direction of Favor	Ecological Significance of Method	Amount of Work Involved	Where it Works Best	Variability	Author/ Reference	Selection Decision Comments
20	Organics in small mammal tissues	Mg contaminant/ kg tissue	The lower the concentrations, the better	Indicates exposure to and bioaccumulation of organic contaminants by small mammals	Collection can take a few days to 1 to 2 weeks; analysis in a few days	Where mammals are present at contaminated soils	Probably high	EPA (1986)	Potentially recommended for protocol to demonstrate exposure
21	Inorganics in soil and/or vegetation, earthworms	Mg contaminant/ kg soil or tissue	The lower the concentrations, the better	Indicates presence of inorganic contaminants in media that small mammals can be exposed	Soil and vegetation collection are quick (hours); earthworms can take days or weeks; lab analysis in days	Where the biota are present at contaminated soils	Site-specific CV about 30% in soil	EPA (1986)	Recommended method for the protocol (for evaluating site-specific exposure of small mammals to inorganic contaminants in food)
22	Organics in soil and/or vegetation, earthworms	Mg contaminant/ kg soil or tissue	The lower the concentrations, the better	Indicates presence of organic contaminants in media that small mammals can be exposed	Soil and vegetation collection are quick (hours); earthworms can take days or weeks; lab analysis in days	Where the biota are present at contaminated soils	Site-specific CV about 30 to100% in soil	EPA (1986)	Potentially recommended method for the protocol (for evaluating site-specific exposure of small mammals to organic contaminants in food)

BEST = Biomonitoring of Environmental Status and Trends.
CV = coefficient of variation.
EPA = U.S. Environmental Protection Agency.
RVAAP = Ravenna Army Ammunition Plant.
USGS = U.S. Geological Survey.
WBG = Winklepeck Burning Grounds.

Table 7-2. Thresholds for Sperm Metrics in Small Mammals

Sperm Parameter (Metric)	How Evaluated	Qualifying Information	References
Count	Statistical comparison with reference site condition	1. All rodents are robustly fertile, producing 10 to 20 times more sperm than needed. 2. A minimum reduction of 80% from the reference site condition is needed to conclude that reproductive success is compromised.	1,2,3 3,4
Motility	Statistical comparison with reference site condition Established benchmark comparison	1. A decrease of 40 to 50% from the "control rate" is necessary to conclude that reproductive success is compromised. 2. Rodents with < 37% motile sperm do not reproduce.	4 4
Abnormality (Morphology)	Statistical comparison with reference site condition	1. An increase in abnormal sperm of 4% or more over the "control rate" means there is compromised reproductive success.	4

1 = Meistrich, M. L., Kasai, K., Olds-Clarke, P., MacGregor, G. R., Berkowitz, A. D., and Tung, K. S. K. 1994. "Deficiency in fertilization by morphologically abnormal sperm produced by *azh* mutan mice." *Molecular Reproduction and Development* **37**:69–77.
2 = Bucci, L. R., and Meistrich, M. L. 1987. "Effects of busulfan on murine spermatogenesis: cytotoxicity, sterility, sperm abnormalities, and dominant lethal mutations." *Mutation Research* **176**:259–268.
3 = Gray, L. E., Marshall, J. O., and Setzer, R. 1992. "Correlation of ejaculated sperm numbers with fertility in the rat." *Toxicologist* **12**:433.
4 = Chapin, R. E., Sloane, R. A., and Haseman, J. K. 1997. "The relationships among reproductive endpoints in Swiss mice, using the Reproductive Assessment by Continuous Breeding database." *Fundamental and Applied Toxicology* **38**:129–142.

Table 7-3. Summary of Individuals[a] Captured at Winklepeck Burning Grounds and Reference Sites, By Species and Capture Location

Species Found	WBG			Reference			Total
	37/38	58/59	66/67	E1/E2 (37/38)	S1/S2 (58/59)	J1/J2 (66/67)	
White-footed mouse *Peromyscus leucopus*	8	15	6	15	10	8	62
Meadow vole *Microtus pennsylvanicus*	5	4	13	4			26
Eastern Cottontail rabbit *Sylvilagus floridanus*		2				2	4
Deer mouse *Peromyscus maniculatur*			1				1
Masked shrew *Sorex cinereus*			1				1
Short-tailed shrew *Blarina brevicauda*				11	3	3	17
Eastern chipmunk[b] *Tamias striatus*				3	29	4	36
Meadow jumping mouse *Zapus hudsonius*					1		1
Southern flying squirrel *Glaucomys volans*					2		2
Woodland vole *Microtus pinetorum*					1		1
Woodland jumping mouse *Napaeozapus insignis*			1				1
Total number of animals captured	**13**	**21**	**22**	**33**	**46**	**17**	**152**
Total for Winklepeck and for Reference	**56**			**96**			**152**

[a]Excludes all recaptures.
[b]Mark/recapture not performed on chipmunks, so totals may include recaptures.
WBG = Winklepeck Burning Grounds.

Table 7-4. Summary of Age and Sex Structure (Number of Individuals[a]) for Target Species, By Capture Location

Age and Sex	WBG			Reference			Total
	37/38	58/59	66/67	E1/E2 (37/38)	S1/S2 (58/59)	J1/J2 (66/67)	
White-footed Mice							
Adults							
Male	3	3	1	4	2	2	15
Female	3	2		4	3	2	14
Sub-adults							
Male		3		2	2	1	8
Female		2	1	2		1	6
Juveniles							
Male		4	3	1	2		10
Female	2	1	1	2	1	2	9
Totals	8	15	6	15	10	8	62
Meadow Voles							
Adults							
Male	1	2	3	1			7
Female	3	1	5	1			10
Sub-adults							
Male				1			1
Female		1	2				3
Juveniles							
Male	1		2	1			4
Female			1				1
Total	5	4	13	4	0	0	26
Grand Total	13	19	19	19	10	8	88

[a]Excludes all recaptures.
E1/E2 = A-9 building.
J1/J2 = airstrip.
S1/S2 = south service road.
WBG = Winklepeck Burning Grounds.

Table 7-5. Number of White-footed Mice and Meadow Voles Collected for Rodent Sperm Analysis at WBG Sites and Reference Sites

Location	White-footed Mouse	Meadow Vole
Reference Site		
Area adjacent to Building A-9	4	1
Area on south service road	2	0
Area at old airfield	2	0
Total	**8**	**1**
WBG Site		
Pads 37 and 38	3	1
Pads 58 and 59	3[a]	2[b]
Pads 66 and 67	1	3[b]
Total	**6**	**4**
Grand Total Analyzed	**14**	**5**

[a]One animal was excluded from totals because it escaped in the laboratory, so it was not analyzed.
[b]One animal was incorrectly identified as an adult and was, therefore, excluded from the totals.
WBG = Winklepeck Burning Grounds.

Table 7-6. Summary Statistics for the White-footed Mouse

Biological Attribute	Number of Results	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Reference Sites						
Sperm Attributes						
Sperm Motility (percent)	8	98.4	1.77	1.8	94	99
Sperm Count (10^6 sperm/g tissue)	8	1670.	353.8	21.2	1178.8	2241.9
Weight Attributes						
Body Weight (g)	8	20.93	2.1037	10.1	18.617	24.098
Liver Weight (g)	8	1.060	0.1466	13.8	0.846	1.232
Left Testis Weight (g)	8	0.217	0.0319	14.7	0.166	0.258
Right Testis Weight (g)	8	0.217	0.0365	16.8	0.169	0.273
Left Epididymis Weight (g)	8	0.071	0.0096	13.5	0.056	0.087
Normalized Weight Attributes						
Liver Weight/Body Weight	8	0.051	0.0066	12.9	0.039	0.061
Left Testis Weightt/Body Weight	8	0.010	0.0012	11.4	0.008	0.012
Right Testis Weight/Body Weight	8	0.010	0.0015	14.4	0.009	0.013
Left Epididymis Weight/Body Weight	8	0.003	0.0004	11.1	0.003	0.004
WBG Sites						
Sperm Attributes						
Sperm Motility (percent)	5	99.2	0.84	0.8	98	100
Sperm Count (10^6 sperm/g tissue)	6	1409.	309.0	21.9	1129.5	1901.7
Weight Attributes						
Body Weight (g)	5	23.01	2.4785	10.8	19.134	25.729
Liver Weight (g)	5	1.264	0.0705	5.6	1.185	1.379
Left Testis Weight (g)	5	0.222	0.0762	34.3	0.113	0.312
Right Testis Weight (g)	5	0.213	0.0751	35.3	0.114	0.305
Left Epididymis Weight (g)	5	0.100	0.0396	39.6	0.044	0.140
Normalized Weight Attributes						
Liver Weight/Body Weight	5	0.056	0.0075	13.6	0.049	0.066
Left Testis Weight/Body Weight	5	0.010	0.0029	30.0	0.006	0.013
Right Testis Weight/Body Weight	5	0.009	0.0028	30.8	0.006	0.013
Left Epididymis Weight/Body Weight	5	0.004	0.0014	33.4	0.002	0.006

WBG = Winklepeck Burning Grounds.

8.0 SOIL-PLANT RELATIONSHIPS

8.1 RATIONALE

Soil and plants interact physically as well as chemically in ecological systems. Characterization of the chemical condition of the soil and the status of the vegetation at WBG sites were selected as study objective 2 of this field investigation. The purposes, statistical methods, and locations for this investigation are explained in Chapters 1.0 (Introduction), 2.0 (Scope, Objectives, and Approach), 3.0 (Statistical Design), and 4.0 (Study Sites). Actual soil data are provided in Chapter 4.0 (Study Sites), and vegetation data are provided in Chapter 6.0 (Vegetation). Soil measurements are closely related to vegetation measurements—both geographically and with respect to objectives.

Although the vegetation data revealed no significant differences between burning pad sites and reference sites on ecologically and spatially relevant scales (i.e., the pad scale), the soil-plant relationships of the plot scale can be used to support objective 2. There are other bare areas at RVAAP, some of which are larger than those found at WBG. Because the level of effort applied at WBG to evaluate an array of plant metrics is not likely to be repeated at other RVAAP areas, the plot-scale soil-plant association information of WBG sites may be used to derive cleanup levels for these other AOCs. Specifically, if at a spatially relevant bare area, the concentration of a soil constituent exceeds that of its cleanup level (based on percent cover of the vegetation), it would seem appropriate to remediate the soil to the cleanup level. For all of its utility, it must be remembered, though, that physical stressors (e.g., compacted soil from past use of trucks, construction equipment, and slag) may also be responsible for the absence of plant cover in a given area. The soil-plant relationships described below focus on the relation between soil chemical concentrations and vegetation characteristics (percent cover, species richness, stem density, biomass, and community composition) and the use of that information to draw a field-observed effects conclusion and to develop a plant protection value or cleanup level.

The correlations between the soil chemical concentrations and the vegetation metrics on collocated plots were analyzed visually using scatter plots and quantitatively using rank correlation analysis. These correlations are described in this section of the report with respect to the strength of the correlation and direction of favorability with respect to ecological effects. A numerical model was fitted to data with correlations that were strong and indicated an adverse ecological effect as described in Chapter 9.0.

The assumption is made in this section that correlations between chemical concentrations and vegetation metrics imply a causal relationship (i.e., that the observed difference in chemical concentration at certain plots causes the observed difference in vegetation measures at those plots). This relationship is important when extrapolating field measurements from one location to another (Chapter 9.0).

The concentrations of chemicals from the reference sites are presented in Chapter 4.0 to show that the reference sites were not contaminated. This is important in establishing cause-effect relationships of chemical concentration to field-observed effects at WBG pads.

The following section describes the methods used for evaluating the soil-plant relationships at contaminated burning pads at WBG sites and reference sites. Statistical methods used to characterize collocated soil and vegetation samples are also provided.

8.2 STATISTICAL ANALYSIS

The goal of study objective 2 was to quantify the relationships between the measured concentrations of contaminants in soil and the measured vegetation metrics for the nine stratified samples from each of the three

burning pad pairs. The pair-wise relationships could be linear, exponential, sigmoidal, or a threshold pattern. Scatter plots were constructed to show the relationship between each vegetation metric and each chemical that was found to be an ecological contaminant of concern in the Winklepeck ERA (USACE 2001).

Inspection of these plots (Appendix H in SAIC 2001) indicated a great deal of scatter but also showed some plots where high chemical concentrations were associated with low values of vegetation metrics. Therefore, Spearman rank correlations were used to screen for pair-wise relationships between the chemical concentrations and the vegetation metrics. The rank correlation test can identify relationships that would be missed by linear correlation tests. As long as one metric changes in a regular manner (increasing or decreasing) with the other, a correlation will be identified. Rank correlation is less sensitive to outliers than a linear correlation test. The rank correlation coefficient varies from +1 to –1. If one measure increases while another measure generally increases, the rank correlation will be close to +1, whether or not the relationship is linear. If one measure increases while another decreases, the rank correlation will be close to –1. If one measure does not vary as a function of another, the correlation coefficient will be close to zero. The rank correlation coefficient indicates the direction and the strength of the correlation. For example, if lead inhibited plant growth, the pair-wise correlation coefficients between lead and the vegetation abundance metrics would be expected to be less than zero. Correlations were considered statistically significant if the probability, p, associated with the Spearman rank correlation coefficient was less than 0.05.

The Ravenna team decided that statistical analyses should focus only on each pad pair individually as opposed to combining all the data across the three pad pairs. One reason for focusing on individual pad pairs was to retain the differences in chemical mixtures among the pads.

8.3 RESULTS

8.3.1 Correlations Between Soil Concentrations and Vegetation Metrics

Correlation coefficients for the Spearman rank correlations were calculated using the soil and plant data from the nine plots at each of the three pad pairs. Each correlation coefficient was, therefore, based on nine samples. Correlations were considered statistically significant when $p<0.05$. For correlations with nine samples, p is less than 0.05 when the absolute value of the correlation coefficient was greater than or equal to 0.67.

Correlations between soil concentrations and percent exotic species and the diversity index were based on seven samples on pads 66/67 because there were two plots with zero stems counted. The diversity index and percent exotic species could not be calculated when there were no stems counted.

Pads 37/38

Five correlations between the soil concentrations and the vegetation metrics were statistically significant ($p< 0.05$) for samples taken on pads 37/38 (Table 8-1). Copper showed a negative correlation and mercury showed a positive correlation with percent cover. One result for copper on pads 37/38 was much higher than any other value (491 mg/kg). If this outlier is ignored, the percent cover generally decreased as the copper concentration increased. Percent cover generally increased as the mercury concentration increased. Mercury also showed a statistically significant positive correlation with biomass. The percent exotic species was positively correlated with aluminum and negatively correlated with cadmium.

These correlations may be indicators that the soil concentrations affect the vegetation. For example, copper has phytotoxic properties and, therefore, the negative correlation may represent an inhibition of

plant growth by the metal. The correlations between copper and the other plant abundance measures, stem density and biomass, were also negative although not statistically significant. The positive correlations between mercury and the plant abundance metrics suggest that mercury may enhance plant growth.

Pads 58/59

On pads 58/59 there were 11 statistically significant correlations ($p<0.05$) between the soil concentrations and the vegetation metrics (Table 8-2). Lead was positively correlated with percent cover. Copper, cyanide, silver, and zinc were positively correlated with biomass. Aluminum, chromium, copper, lead, manganese, and zinc were positively correlated with species richness. These correlations are the opposite direction than would be expected if metal concentrations had a detrimental effect on the vegetation. Higher metal concentrations appear to be correlated with increased plant abundance and increased number of species.

Pads 66/67

On pads 66/67 there were 12 statistically significant correlations ($p<0.05$) between the soil concentrations and the vegetation metrics (Table 8-3). Arsenic concentrations were positively correlated with percent cover, biomass, and stem density. The direction of this correlation is opposite that expected if arsenic inhibited plant growth. Cyanide, 1,3,5-TNB, and 2,4,6-TNT had statistically significant negative correlations with percent cover. Thallium had a negative correlation with species richness. Barium, 1,3,5-TNB, and 2,4,6-TNT had statistically significant positive correlations with the percent of exotic species while selenium had a significant negative correlation with the percent of exotic species. Cadmium concentrations were positively correlated with the diversity index.

Cyanide and explosives were correlated with each other and with the percent of exotic species and negatively correlated with plant abundance metrics. These correlations are consistent with the chemicals having a negative effect on plant growth and allowing the invasion of exotic species.

Higher arsenic concentrations were positively correlated with the vegetation abundance metrics. This correlation indicates that arsenic may enhance rather than inhibit plant growth.

8.3.2 Considerations of Soil Types

Soils within the WBG are represented by five soil-mapping units: Bogart-Haskins complex (2 to 6% slopes), Ellsworth silt loam (2 to 6% slopes), Jimtown loam (0 to 2% slopes), and Mahoning silt loam (0 to 2 and 2 to 6% slopes) [Ritchie et al 1978]. All soils at WBG formed in a variety of parent materials of glacial origin. All soils at WBG are classified as deep to very deep. Soil drainage classes vary from moderately well drained (Bogart and Ellsworth series) to somewhat poorly drained (Jimtown, Haskins, and Mahoning series). Slight differences in parent materials and hydrologic conditions at the site are reflected in the texture, permeability, and relative productivity of each soil type. The physical and chemical properties of these soils have been further modified by past agricultural activities at RVAAP and by earth-moving activities and waste disposal activities at WBG (SAIC 1999b).

The physical and chemical properties of each soil type, along with the disturbance history and other past land use practices, have influenced the types of plant communities that have developed at the site. Areas subjected to frequent or highly disruptive disturbance tend to be dominated by grasses, grass-like plants, and forbs. In less highly disturbed areas or areas not subjected to disturbance for long periods of time, shrubs and small trees may dominate. If past disturbance has been slight or absent for very long periods of time, forests or woodlands may develop. Forests and woodlands are rare within WBG. Areas where soils

have been very highly disturbed may remain bare until the soil-forming factors can rebuild soils to the point where they can support plant-life (SAIC 1999b).

Biological field sampling personnel were not permitted in the sampling areas while intrusive sampling occurred; rather, UXO technicians performed the soil sampling under the direction of the biological field sampling personnel. Detailed boring logs and soil descriptions are not available. Soil samples for explosives were composited from three points within each plot and deposited directly into stainless steel bowls for compositing. When composited sample material was transferred back to the sample management team for sample preparation, there was no way to determine the stratigraphic position of the soil material in each soil profile could no longer be determined. Similarly, the discreet sample for the other analytical analysis do not have detailed boring logs or soil descriptions.

Pads 37, 38, and possibly pad 66 were constructed with fill material scraped and transported from other locations (most likely within Winklepeck); pads 37 and 38 were later covered with slag. Scraped soil materials could have come from any location in the soil profile but most likely originated from the surface horizon and the top of the subsurface horizon. Likewise, pads 58, 59, and 67 were constructed by scraping and excavating native soils. The resulting surface and near-surface soil horizons at these three pads are now likely composed of the subsoil originally found at each of these sites. Specific soil properties at each filled or cut location would vary widely depending on the physical and chemical properties of the original source material as well as degree of compaction, the location of the present soil surface in relation to its original location in the soil profile, changes in soil physical and chemical properties caused by local hydrology, and other human-caused activities at each receiving or donor site.

Places devoid of vegetation (bare spots) could result from physical properties (poor or excessive internal drainage or soil compaction), chemical properties (excessive concentrations of contaminants that interfere with seed germination or plant growth), or some combination of physical and chemical properties. Plant cover at locations with heavy slag cover (pads 37 and 38 and reference site E) was generally much lower than other sampling locations, possibly because of the slag acting as a barrier to prevent seeds from finding a suitable germination bed rather than because of any chemical interference from slag.

8.4 DISCUSSION AND UNCERTAINTIES

Chemical concentrations in soil are heterogeneous, and there is also variability in plant metrics, which, therefore, present a challenge to establish tight cause/effect relationships. Spatial heterogeneity of soil contamination creates variation in the degree of plant exposure and in possible ecological effects. For example, the concentration of 2,4,6-TNT was measured in eight samples on pad 67 within a 5-m radius of plot 132. The concentrations ranged from 2.3 to 2,000 mg/kg, nearly a thousand-fold difference. There were also six plots within that same radius that were sampled for vegetation but not soil. While the assumption was that these vegetation plots had a similar concentration distribution to those plots where soil concentrations were measured, they could also be less contaminated or more contaminated.

The distributions of chemicals are not independent of each other. Samples that have elevated concentrations of one explosive tend to have elevated concentrations of other explosives as well. Some inorganics, such as antimony, barium, copper, cyanide, lead, manganese, mercury, and zinc, tend to be positively correlated with the explosives concentrations (Table 8-4). Cobalt and nickel tend to have negative correlations with the explosives. These correlations most likely relate to the composition of the materials that were burned at the site. As anticipated, the correlated chemical concentrations complicate the interpretation of the relationships between individual chemicals and the vegetation metrics. This relationship between a chemical and vegetation metric must be interpreted with caution.

Historically, burning was practiced on burning pad sites but not at reference sites. Likewise, burning intensity was variable across burning pads, possibly leading to more soil damage where fires were more intense. These differences in burning may have affected both plant and animal habitat. These differences in land use and in burning intensity result in uncertainty about effects of burning on plant habitat (as opposed to chemical effects). Reference sites were chosen to match the WBG sites with respect to soil type, hydrology, topography, degree of maintenance (i.e., mowing), and plant community type. Sites were also matched with respect to the time of the most recent disturbance. The burning that occurred on the WBG sites was likely a different type of disturbance than that which occurred at the reference sites. The burning that occurred at the WBG sites may have changed the organic content of the soils, destroyed seeds and rhizomes, and affected the soil structure and texture. Changes to the seed stock and physical structure of the soil from burning may affect the ability of vegetation to colonize and grow in these soils. There is, therefore, some uncertainty as to whether differences in vegetation between the WBG and reference sites are caused by physical (i.e., fire) or chemical differences between the sites.

High concentrations of explosives and cyanide caused a decrease in vegetation abundance (percent cover, stem density, and biomass) and an increase in the percent of exotic species at the plot scale. Other confounding factors can cause the observed reductions in percent cover, stem density, and biomass and an increase in percent of exotic species. Frequent, high-intensity fires as would be expected as part of the normal operations of the WBG can cause changes in soil structure, chemistry, physical parameters and soil flora. This can result in changes in the measured floristic parameters. In addition, soil compaction, gravel, and cinders can also alter the measured parameters. While it may be true that contamination is the cause of the observed floristic community differences, the physical disturbance of the soil can be equally responsible for these differences. Thus, a strong causative statement concerning soil contamination and floristic community changes cannot be made.

Aluminum is no longer a chemical of concern. As explained in Section 4.3.7, aluminum is not bioavailable to plants at soil pH values > 5.5. Soil pH measurements at WBG and background sites were all between pH 8 and 9. Thus, aluminum is not expected to be bioavailable.

The ecological consequences of correlations may be confounded and even coincidental. One chemical may be confounded with one or more other chemicals**.** This means that an observed effect may not be easily isolated and associated with any one substance. Mixtures of chemicals may have multiple effects on organisms, and combinations of multiple chemicals may result in more, fewer, or different effects from the sum of the effects of each chemical separately.

8.5 CONCLUSIONS AND SUMMARY

A specific study was conducted to determine, if possible, soil contaminant concentrations that would be considered protective of vegetation and animal receptors. Due to the limited samples obtained for the small mammal study, protection levels for these receptors could not be developed. However, protection levels for vegetation were derived and are presented in the following text.

Sample plots were selected for co-located soil and vegetation sampling at each WBG pad pair such that three plots represented sparse vegetation cover (0 to 29%), three represented medium cover (30 to 69%), and three represented high cover (70 to 100%). The measurements for the nine plots at each pad pair were examined visually and statistically for correlations between the soil concentrations and each of the vegetation metrics. Visually means inspection of the scatter of the data points in an x,y plot. Statistically significant correlation (probability < 0.05) were taken as evidence of a potential for a cause/effect relationship between the soil concentrations and the vegetation. The definition of geographical scale is the plot or approximately 1m by 1m patches. This scale was adopted for the correlations because adverse

effects, such as areas devoid of vegetation, were identified at isolated locations. It was expected that if predictable dose-response relationships could be identified, then it would be at a scale less than the pad. The observed correlations indicate the following:

1) High concentrations of explosives (HMX, RDX, 1,3,5-trinitrobenzene, and 2,4,6-trinitrotoluene) and cyanide appeared to caused a decrease in vegetation abundance (percent cover, stem density, and biomass) and an increase in the percent exotic species at the plot scale.

2) High concentrations of metals were in general associated with increased vegetation abundance especially at pad pair 58/59. Copper was associated with decreased vegetation abundance at pad pair 37/38. High concentrations of metals did not consistently cause an adverse ecological effect to vegetation at WBG.

TABLES

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Table 8-1. Correlations Between Chemical Concentrations and Vegetation Metrics for Pad Pair 37/38[a]

COPECs from WBG Phase II RI	Percent Cover	Stems Density	Biomass	Species Richness	Proportion Exotic Species	Diversity Index
Aluminum	0.08	0.54	-0.06	-0.25	**0.69**	-0.09
Arsenic	-0.15	-0.47	-0.02	-0.29	-0.44	-0.37
Barium	0.13	0.38	-0.05	-0.05	0.43	0.18
Cadmium	-0.44	-0.59	-0.41	0.19	**-0.71**	0.32
Chromium	0.32	0.62	0.45	-0.24	0.53	-0.50
Cobalt	-0.17	-0.50	0.08	-0.14	-0.54	-0.35
Copper	**-0.67**	-0.20	-0.45	-0.33	-0.15	-0.63
Cyanide	0.17	-0.22	-0.09	0.19	0.10	0.52
Lead	-0.07	0.32	-0.02	0.00	0.41	0.22
Manganese	0.30	0.30	-0.03	0.14	0.47	0.35
Mercury	**0.92**	0.65	**0.78**	0.52	0.00	0.28
Nickel	-0.52	-0.47	-0.17	-0.27	-0.46	-0.50
Selenium	-0.13	-0.52	-0.21	-0.22	-0.20	-0.27
Silver	0.00	-0.41	0.10	-0.16	-0.05	-0.10
Thallium	0.45	0.39	0.37	0.06	0.22	-0.24
Zinc	-0.52	-0.05	-0.43	-0.04	-0.08	0.02
HMX	0.41	0.27	0.55	0.41	-0.48	0.00
RDX	-0.34	-0.32	-0.37	-0.02	0.31	0.27
1,3,5-Trinitrobenzene	-0.37	-0.46	-0.23	-0.14	-0.50	0.14
2,4,6-Trinitrotoluene	-0.29	-0.34	-0.32	-0.37	-0.58	-0.22

[a]The values listed in this table are Spearman rank correlation coefficients. Coefficients that are significant at the 0.05 probability level are in bold type.

COPEC = contaminant of potential environmental concern.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RI = Remedial Investigation.
WBG = Winklepeck Burning Grounds.

Table 8-2. Correlations Between Chemical Concentrations and Vegetation Metrics for Pad Pair 58/59[a]

COPECs from WBG Phase II RI	Percent Cover	Stems Density	Biomass	Species Richness	Proportion Exotic Species	Diversity Index
Aluminum	0.50	-0.10	0.35	**0.74**	-0.28	0.05
Arsenic	-0.51	-0.54	-0.31	-0.25	-0.44	0.57
Barium	0.46	0.20	0.65	0.52	-0.58	0.07
Cadmium	0.32	0.27	0.58	0.50	-0.52	0.30
Chromium	0.64	0.23	0.60	**0.73**	-0.40	0.00
Cobalt	0.08	-0.23	0.13	-0.46	0.17	-0.28
Copper	0.58	0.47	**0.73**	**0.70**	-0.40	-0.07
Cyanide	0.59	0.49	**0.71**	0.58	-0.02	0.20
Lead	**0.70**	0.28	0.63	**0.82**	-0.30	0.03
Manganese	0.59	0.23	0.55	**0.76**	-0.48	-0.23
Mercury	0.27	0.40	0.47	0.31	-0.33	0.27
Nickel	-0.05	-0.37	0.18	0.03	-0.53	0.30
Selenium	0.53	0.33	0.65	0.58	-0.45	0.02
Silver	0.65	0.48	**0.82**	0.56	-0.40	-0.14
Thallium	-0.41	-0.29	-0.27	-0.45	-0.07	0.27
Zinc	0.61	0.42	**0.75**	**0.73**	-0.42	-0.02
HMX						
RDX	-0.28	0.18	-0.27	-0.28	-0.46	0.09
1,3,5-Trinitrobenzene						
2,4,6-Trinitrotoluene	0.42	-0.14	0.41	0.28	0.27	-0.14

[a]The values listed in this table are Spearman rank correlation coefficients. Coefficients that are significant at the 0.05 probability level are in bold type.

COPEC = contaminant of potential environmental concern.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RI = Remedial Investigation.
WBG = Winklepeck Burning Grounds.

Table 8-3. Correlations Between Chemical Concentrations and Vegetation Metrics for Pad Pair 66/67[a]

COPECs from WBG Phase II RI	Percent Cover	Stems Density	Biomass	Species Richness	Proportion Exotic Species	Diversity Index
Aluminum	0.20	0.06	0.06	0.63	-0.41	-0.54
Arsenic	**0.93**	**0.71**	**0.71**	0.59	-0.71	0.50
Barium	-0.44	-0.19	-0.19	-0.59	**0.86**	0.00
Cadmium	-0.16	-0.24	-0.24	-0.39	0.21	**0.79**
Chromium	-0.28	0.04	0.04	0.21	0.54	-0.14
Cobalt	0.15	0.06	0.06	0.41	-0.56	0.02
Copper	-0.31	-0.14	-0.14	-0.23	0.71	0.29
Cyanide	**-0.75**	-0.60	-0.60	-0.58	0.63	0.07
Lead	-0.44	-0.41	-0.41	-0.33	0.54	0.21
Manganese	-0.45	-0.48	-0.48	-0.48	0.14	0.50
Mercury	-0.09	0.18	0.18	-0.24	0.64	0.25
Nickel	0.39	0.09	0.09	0.53	-0.56	0.41
Selenium	0.26	-0.14	-0.14	-0.03	**-0.85**	0.26
Silver	-0.17	-0.15	-0.15	-0.05	-0.40	0.09
Thallium	-0.19	-0.33	-0.33	**-0.67**	-0.18	0.16
Zinc	-0.02	0.07	0.07	-0.17	0.46	0.50
HMX	-0.52	-0.55	-0.55	-0.49	0.27	0.20
RDX	-0.42	-0.38	-0.38	-0.34	0.29	0.07
1,3,5-Trinitrobenzene	**-0.76**	-0.49	-0.49	-0.53	**0.86**	-0.07
2,4,6-Trinitrotoluene	**-0.84**	-0.50	-0.50	-0.45	**0.86**	-0.43

[a]The values listed in this table are Spearman rank correlation coefficients. Coefficients that are significant at the 0.05 probability level are in bold type.

COPEC = contaminant of potential environmental concern.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
RI = Remedial Investigation.
WBG = Winklepeck Burning Grounds.

Table 8-4. Correlations Between Inorganics and Explosives Concentrations[a]

Analyte	HMX	RDX	1,3,5-TNB	2,4,6-TNT	2,4-DNT
Aluminum	-0.20	-0.22	-0.31	-0.06	0.10
Antimony	**0.62**	**0.66**	**0.48**	**0.42**	-0.11
Arsenic	-0.25	-0.17	-0.28	-0.12	0.11
Barium	**0.77**	**0.73**	**0.65**	**0.60**	0.25
Beryllium	-0.02	-0.07	-0.07	-0.04	0.32
Cadmium	0.07	0.15	0.29	0.25	0.25
Calcium	0.00	0.01	0.05	-0.07	0.23
Chromium	0.20	0.27	0.21	0.14	-0.22
Cobalt	**-0.61**	**-0.50**	**-0.57**	**-0.48**	**-0.49**
Copper	**0.45**	**0.48**	**0.48**	0.37	0.21
Cyanide	**0.85**	**0.78**	**0.73**	**0.74**	0.19
Iron	-0.24	-0.15	-0.22	-0.07	0.06
Lead	**0.58**	**0.62**	**0.48**	**0.47**	0.09
Magnesium	-0.24	-0.20	-0.30	-0.24	0.18
Manganese	**0.65**	**0.56**	**0.54**	**0.60**	0.34
Mercury	**0.60**	**0.66**	**0.54**	**0.45**	0.18
Nickel	**-0.45**	-0.31	**-0.42**	**-0.40**	-0.31
Potassium	-0.22	-0.18	-0.32	**-0.39**	-0.33
Selenium	-0.12	-0.02	-0.28	-0.13	0.11
Silver	-0.17	0.00	-0.11	-0.18	-0.28
Sodium	0.21	0.19	0.32	0.23	0.25
Thallium	0.08	0.07	-0.15	-0.11	-0.20
Vanadium	-0.02	-0.03	-0.25	-0.06	-0.10
Zinc	**0.39**	**0.45**	**0.47**	0.36	0.33

[a]The values listed in this table are Spearman rank correlation coefficients. Coefficients that are significant at the 0.05 probability level are in bold type.
DNT = dinitrotoluene.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
TNB = trinitrobenzene.
TNT = trinitrotoluene.

9.0 EXTRAPOLATIONS OF BIOLOGICAL FIELD MEASUREMENTS TO OTHER AREAS OF CONCERN AT RAVENNA

9.1 RATIONALE

Extrapolating field measurements from one place to another place includes a number of activities. For example, extrapolating can be from selected places inside WBG to other places inside WBG, as well as from WBG to other places at Ravenna. In this section, extrapolation is defined and its roles and advantages explained. This is followed by an analysis of chemical concentrations associated with no to little ecological effect to vegetation. Other field measurements may be less quantitative, but also useful, as explained in the weight-of-evidence analysis for small mammals (Chapter 7.0). Third, the marriage of extrapolation and field effects, or lack of them, deserves discussion.

9.2 EXTRAPOLATION

Extrapolation means the transfer of knowledge acquired in one situation to a different situation. For example, a biological effect or lack of effect on vegetation or small mammals that is measured in one place should be transferable to another place that is similar to the place of documentation, assuming there is not sufficient time and money to take another measurement.

Extrapolation is an effective way to save time and money. Environmental problem solving can be expensive. Any technique is desirable that can transfer lessons learned at one situation to another situation and do this at less investment than having to repeat all the work.

Extrapolation is a part of many scientific activities because of the constancy of laws and principles that prevail in the natural world. For example, a group of organisms that is healthy after being exposed to a combination of metals at specified concentrations should presage the healthy response of a different group of the same species living in a similar but different location where the exposure medium (e.g., soil) and chemical mixtures are similar to the first location.

Conventional extrapolation of ecological effects in risk assessment involves transfers of data from laboratory measurements to field applications. In the laboratory, conditions are controlled so that cause and effect relationships can be clearly documented. It is only natural that we depend on dose-response data based on laboratory conditions. Laboratory experiments provide numbers that are extrapolated to the environmental conditions at a particular place and used in screening ecological risk assessments to pinpoint potential problems.

There are at least four interrelated intellectual obstacles to extrapolating from laboratory to field conditions. These barriers, and to the more desirable condition in the field, follow:

- single variable, confined laboratory setting versus multi-variable, realistic environments (e.g., WBG);
- single chemical exposures in the laboratory versus chemical mixtures in the field;
- laboratory plants and animals versus wild organisms in the field; and
- exposures of short duration in the laboratory versus exposures involving multiple generations in the field.

Thus, the laboratory represents a radically different situation from *in situ* conditions typical of the real world.

Field-observed effects remove most of the inherent problems with conventional extrapolations. By taking measurements directly in the field rather than the laboratory, the barriers are removed. For example, weather, temperature, and other conditions interact. Chemicals occur in mixtures of inorganics and organics, not single chemical doses as in the laboratory. Organisms are wild and have lived in the field environment where predators, parasites, and food interact with them continuously. Often, many generations of organisms have experienced the conditions in the real environment and may have adapted to chemical exposures.

There are a number of environmental variables that need to be similar about the extrapolated-from environment and the extrapolated-to environment. Similarity of these environmental attributes increases the likelihood of a technically sound extrapolation. Key environmental similarities include soil, vegetation, and chemical history.

Candidate locations for extrapolations may be at Ravenna because of their similar environments and use histories. For example, soil types, habitats, and chemical-use history are the same or similar at many locations. Also, the numerous Load Lines and Demolition Areas exhibit similar environmental conditions.

It is the Army's intent to extrapolate findings from one field place to other field places at Ravenna. WBG chemical conditions are among the worst at Ravenna. It would be reasonable to study plants and animals at WBG and, then, to transfer these findings to one or more of the Load Lines and Demolition Areas where environmental conditions are similar.

9.3 DEVELOPMENT OF PPLS BASED ON PLOT SCALE EXTRAPOLATION

PPLs are the lowest chemical concentrations below which we have not measured or would not expect to measure a significant ecological effect. A significant ecological effect is a 20% effect based on the team consensus. A 20% reduction from the mean value for a metric compared with the matched reference site is the PPL.

The collocated measurements of soil concentrations and vegetation metrics showed that some chemicals at WBG have some ecological effects (see Chapter 8.0). A dose-response model is needed to better define the PPL and to extrapolate this information to other locations.

9.3.1 Nonlinear Dose-response Model

A nonlinear dose-response model was fitted to the measurements of chemicals and vegetation that were related as indicated by statistically significant rank correlations ($p < 0.05$), visual inspection of the scatter plots and direction of favorability (i.e., ecologically adverse). The soil concentration was the independent variable, and the vegetation metric was the dependent variable. The hypothesis was that the chemical concentration predicted the vegetation metric. Fitting a numerical model to the data provides a way to quantify the effect of soil chemical concentrations on the vegetation. The model is an equation that allows for interpolation and extrapolation of the data. Thus, the model can predict effects for sites where biological measurements were not taken in the field.

There are many equations that could be fit to the WBG soil-plant data. The considerations in choosing an equation include:

- the shape of the curve fitting the data,
- the number of model parameters,
- and the process that the model represents.

The shape of a plot of the model equation should match the shape of the distribution of the field measurements. The equation chosen should use the smallest number of parameters required to obtain the observed shape. The equation should theoretically represent the biological process occurring in the field.

In searching for a dose-response equation to fit to the data of collocated soil concentrations and vegetation metrics, the team discovered that the National Center for Environmental Assessment of the EPA is developing protocols for determining benchmark doses. While the "Benchmark Dose Technical Guidance Document" is in "available as a preliminary draft" status, the Center has already developed software that may be used to fit various model equations to data. The software fits models for dichotomous data (Gamma, Logistic, Log-Logistic, Multistage, Probit, Log-Probit, Quantal-Linear, Quantal-Quadratic, Weibull) and continuous data (Linear, Polynomial, Power, Hill).

The Hill equation was chosen to model the relationship between soil concentrations and vegetation metrics for our study. The Hill model can fit a sigmoidal dose-response curve – like some of the data that were collected for this study. The shape allows for a plateau where the concentration changes with no effect on the vegetation, a slope where the metric declines with increasing concentration, and another plateau where further increase in concentration has no additional effect on the vegetation.

The Hill model has the form:

$$\text{Response}=\text{Control}+\text{Sign} \times \text{Dose}^n / (\text{Dose}^n + \text{Slope}^n)$$

Thus, the model has four parameters that must be fitted:

Control -- base level of the metric
Sign -- direction and magnitude of effect
Slope -- slope of the threshold
N -- power term

A non-linear, curve-fitting program is used to adjust the parameters until the curve best fits the measured data. There was some difficulty getting the EPA software to produce usable output so the EPA equations were to fit the model with the SAS statistical package. The Marquardt method in the SAS® NLIN procedure was used (SAS 1990). If any of the parameters are known, they can be assigned a value and, therefore, not have to be fitted. In the case of soil relationships with percent cover, the control parameter may be set to 100% because that is the expected value of percent cover when there is no effect from the chemical. For the other vegetation metrics, the control parameter is not known and must, therefore, be fitted.

9.3.2 Application of Hill Model to Develop PPLs

The proportion of the variability in the dependent variable (vegetation metric) that could be explained by the independent variable (chemical concentration) was calculated for each model as a measure of the goodness of fit of the model. This is the equivalent of r^2 for a linear regression. If 100% of the variability of the dependent variable could be explained by the independent variable, this would mean that all of the

measurements fall on the line that represents the model equation. Fitted models were considered statistically significant if the probability that the data did not fit the model was <0.05.

The method for developing a PPL is illustrated using the data for 2,4,6-TNT and percent cover from pads 66/67 (Figures 9-1a through 9-1c). First, the Hill model was fit to the data using the SAS® NLIN procedure (SAS 1990). The non-linear, curve-fitting program takes initial guesses of the model parameters supplied by the user and uses an algorithm to adjust the parameters until differences between the model curve and the observations are minimized. Unlike a linear model, a non-linear model does not necessarily have a unique set of parameters that best fits a particular set of data. In some cases the curve-fitting program cannot converge on a set of parameters that results in minimal differences between the model curve and the observations. In other cases the curve-fitting program may find different sets of parameters depending upon what initial parameter values were used.

For 2,4,6-TNT and percent cover from pads 66/67, the program was able to determine a set of parameters. The control parameter was set at 100% because that was the expected level of percent cover with no chemical effect. The program determined the following parameters:

Sign	-87.92
Power	1.6796
Slope	147.4

The model explained 94% of the variance in percent cover and the test statistic was significant (p=0.0005). The model curve appeared to fit the data (Figure 9-1a).

After the model parameters have been fit to the data, the program can estimate the uncertainty associated with the mean prediction of percent cover for any concentration of 2,4,6-TNT. The confidence of the prediction can be calculated for any probability level desired using the t-statistic. Confidence limits of 80%, 90%, and 95% were calculated and plotted (Figure 9-1b). The larger the value of the confidence limit, the farther the limit plots from the model curve.

The model curve and confidence limit curves may then be used to determine the PPL and confidence limits on the PPL. The PPL is the lowest concentration above which the team would expect to have a significant ecological effect. Based on the team consensus that a 20% effect would be ecologically significant, the team chose a 20% reduction from the mean value of the metric at the matched reference site as the significant effect level. The mean vegetation metric levels for the reference sites may be found in Tables 6-4 and 6-5 of this report. The mean value of percent cover at J1/J2, the reference site for pads 66/67, was 99.5%. Taking 80% of the reference mean level would make the reference effect level 80% cover. To find the PPL, first find the reference effect level (80% cover) on the vertical axis. Then, move horizontally to the model curve. Then, move vertically down to read the PPL concentration on the horizontal axis (Figure 9-1c). This concentration is the PPL (71 mg/kg for 2,4,6-TNT and percent cover from pads 66/67).

The lower confidence limits on the PPL may be determined by following the reference effect level until it intersects the desired lower confidence bound and then moving vertically down to read the concentration off the horizontal axis. For 2,4,6-TNT and percent cover from pads 66/67, the lower confidence limits on the PPL would be 31, 25.4, and 21.8 mg/kg for the 80%, 90%, and 95% lower confidence limits, respectively.

The statistically significant correlations (p<0.05) between soil concentration of contaminants of potential environmental concern (COPECs) at WBG and the vegetation metrics described in Chapter 8.0 of this report are summarized in Table 9-1 for all three WBG pad pairs. The table has the name of the pad pair

and the sign of the correlation in the table cell for each significant correlation. First note that there were no chemical/vegetation correlations that were significant at more than one WBG pad pair. This indicates that there was no chemical effect on the vegetation that was strong enough to be apparent at more than one pad pair.

Many of the correlations are in the opposite direction than would be expected if the chemicals were causing harm to the environment. For example, all of the significant correlations between arsenic and the vegetation abundance metrics were positive. That means that higher arsenic concentrations were associated with more abundant vegetation at pads 66/67. These data do not indicate an adverse effect of arsenic; therefore, a PPL was not computed from them.

Based on the significant correlations and adverse direction of effect, numerical models were fitted to the relationships for the following data:

Analyte	Vegetation Metric	Pad Pair
Aluminum	Percent Exotic Species	37/38
Barium	Percent Exotic Species	66/67
Copper	Percent Cover	37/38
Cyanide	Percent Cover	66/67
Thallium	Species Richness	66/67
1,3,5-Trinitrobenzene	Percent Cover	66/67
1,3,5-Trinitrobenzene	Percent Exotic Species	66/67
2,4,6-Trinitrotoluene	Percent Cover	66/67
2,4,6-Trinitrotoluene	Percent Exotic Species	66/67

Most of the significant adverse effects were seen with the percent cover and percent exotic species metrics, and most were seen in the data from pads 66/67.

Aluminum information is presented here for completeness. However, aluminum is not a chemical of concern at WBG because of no to low bioavailability, based on soil pH, as explained in Section 4.3.7.

The results for the non-linear curve fitting are reported in Table 9-2. Using the Hill equation, four models were successfully fitted to the data and allowed for the estimation of PPLs. All four models were the relationship between chemicals with percent cover: copper at pad pair 37/38 and cyanide, 1,3,5-TNB, and 2,4,6-TNT at pad pair 66/67.

For copper at pads 36/37, the percent cover decreased as the copper concentration increased (Figure 9-2). The model explained 89% of the variation in the percent cover. The mean percent cover at the reference site was 80.9%. The reference effect level would, therefore, be 65% (80% of 80.9). The modeled concentration at 65% cover and, therefore, the PPL was 17.1 mg/kg. The 80%, 90%, and 95% confidence limits are shown in Table 9-2.

The relationship between cyanide and percent cover at pads 66/67 showed a sharp threshold relationship (Figure 9-3). Because of this sharp threshold, the PPL is very well defined and has very narrow confidence bounds (Table 9-2).

The relationship between 1,3,5-TNB and percent cover at pads 66/67 showed a decline in percent cover as the concentration increased (Figure 9-4). The PPL determined from the modeled concentration at 80% cover was 0.86 mg/kg. The confidence bounds on the PPL are reported in Table 9-2. The relationship between 2,4,6-TNT and percent cover at pads 66/67 showed a decline in percent cover as the concentration increased (Figure 9-1c). This curve was used above to illustrate the determination of PPLs.

The PPL determined from the modeled concentration at 80% cover was 71 mg/kg. The confidence bounds on the PPL are reported in Table 9-2.

The curve-fitting program could not converge on a set of parameters for three of the relationships. The relationships between aluminum and percent exotic species at pads 37/38 (Figure 9-5) and between barium and percent exotic species at pads 66/67 (Figure 9-6) both showed highest percent exotic species at the highest concentration, but a unique Hill model could not be determined. The relationship between thallium and species richness showed lower species richness at higher concentrations (Figure 9-7), but the model could not be fit to the data.

For the relationships of 1,3,5-TNB and 2,4,6-TNT with percent cover at pads 66/67, a model curve could be fit, but PPLs could not be determined. The shape of the curves was such that the PPL was not defined or essentially zero.

9.3.3 Qualitative Reference Values

For pads on which the team concluded that there is no adverse ecological effect of the soil chemicals, a soil concentration representative of the pads may be assumed to represent a qualitative reference value or potential PPL. The team computed summary statistics for the collocated soil samples on each pad pair and for all three sites (Tables 9-3 through 9-6) and also for those soil samples that were inside the vegetation grid and inside the burning pads at each site from all RI/FS and ecological studies at WBG (Tables 9-7 through 9-10). As stated above, these data constitute additional soil concentrations associated with the lack of demonstrated ecological effects to plants. Uses for PPLs and these qualitative reference values will be further developed in the RVAAP Facility-wide Ecological Risk Work Plan.

9.4 DISCUSSION AND UNCERTAINTIES

Multiple natural and man-induced processes in the field make it difficult to select an equation to represent available dose-response data. Indeed, any equation represents the theoretical effect of a chemical on an ecological receptor. The Hill model used in this analysis represents the binding of a chemical inside a plant (or animal) receptor whose binding interrupts a physiological process. If there are different chemicals reacting with different affinities to the same or different receptors, the shape of the relationship between the measured soil concentration and vegetation metric may not fit the theoretical shape for a single chemical and response.

The small sample size of nine co-located soil and vegetation samples per pad pair site limited the type of dose-response equation(s) and its (their) fit to the data. Dose response equations usually have numerous parameters that must be calibrated for the model to fit the measured data. For example, the Hill model has four parameters that must calibrated. At a minimum there must be more measurements than parameters in the model. In addition, there must be data points throughout the range of the response so that the shape of the response is well defined. If there are insufficient points to define the curve, a unique set of parameters cannot be determined for the model.

Confidence limits of 80%, 90%, and 95% are estimated for the PPLs. Confidence limits reflect the uncertainty of the measured vegetation metrics and soil concentrations as well as the limited number a data points available for fitting the model equation. Confidence limits provide a way to quantify the uncertainty of the PPL estimate given the chosen model and measured results.

9.5 CONCLUSIONS AND SUMMARY

Numerical modeling of soil chemical concentrations was conducted to develop plant protection levels (PPLs). PPLs are the lowest soil concentration at which we would expect to measure a significant (greater than 20%) ecological effect. From the analysis conducted we conclude:

1) The Hill model fits the nonlinear dose-response curves observed at WBG.

2) PPLs protective of vegetation can be developed from the dose-response data for the following chemicals:

Chemical	**General screen[a] (mg/kg)**	**PPL (mg/kg)**	**95% Confidence limit (mg/kg)**
Copper	100	13.9	4.81
Cyanide	No Value	1.08	1.06
1,3,5-trinitrobenzene	No Value	0.86	0.027
2,4,6-trinitrotoluene	140	71.0	21.8

[a]The general Screening Value is based on the hierarchy of preferred ecological benchmarks used in the HQ re-screen process.

3) If a site has no ecological impact, then the arithmetic mean soil concentrations (inside the pad boundaries) at that site may be used as a qualitative reference value for other similar sites (*e.g.*, similar soil, habitat, receptors, chemical contamination and distribution etc.).

4) Confidence varies from chemical to chemical with more confidence in the dose-response data from the Hill model and lower confidence in the other data that were not fitted to a dose-response model.

5) The future decision to extrapolate the various types of PPLs from WBG to other sites is a risk assessment recommendation and a risk management decision.

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FIGURES

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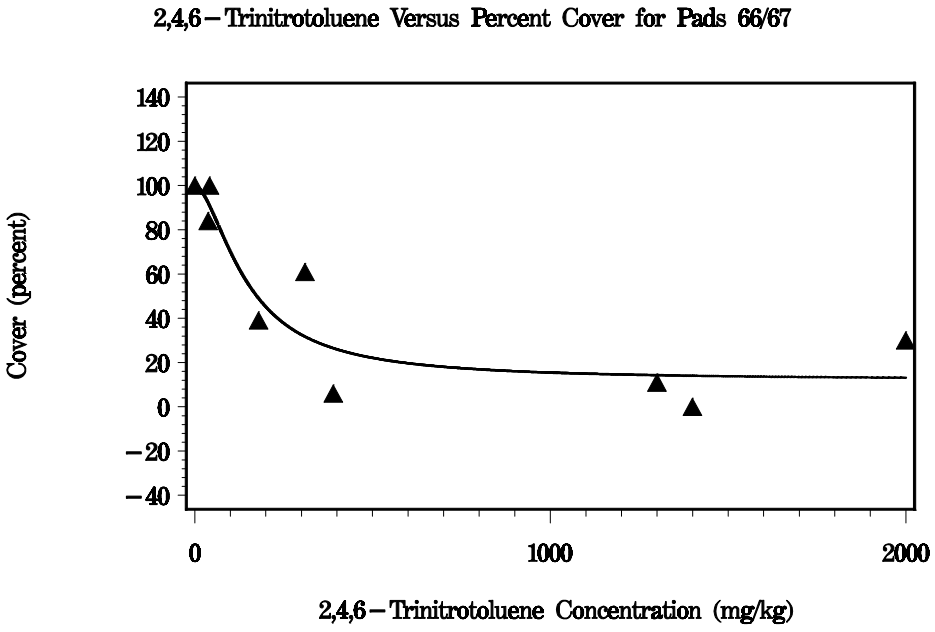

Figure 9-1a. Hill model curve fitted to 2,4,6-Trinitrotoluene concentrations and percent cover for pads 66/67. Solid curve is the fitted model. Triangles represent the individual measurements.

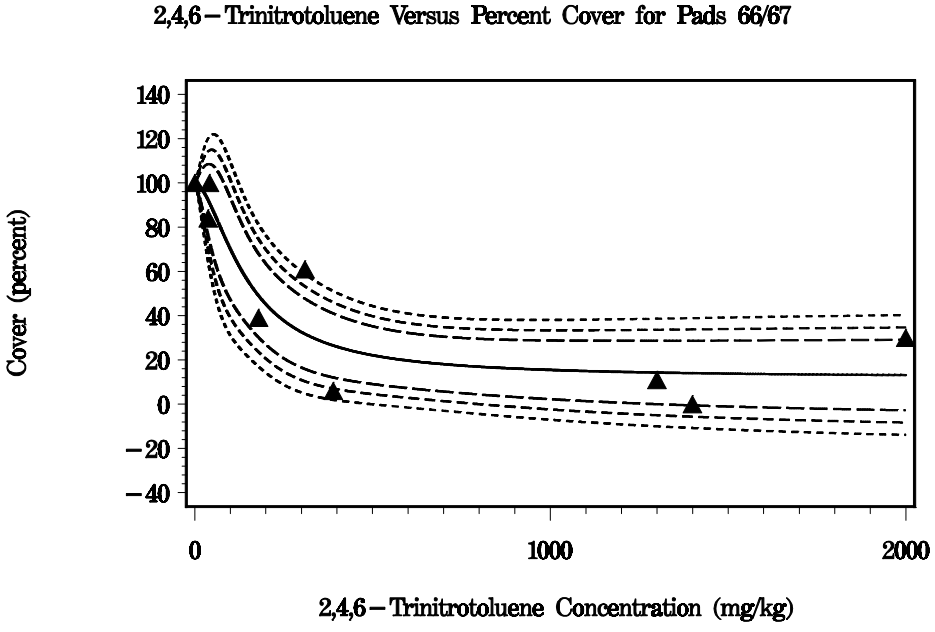

Figure 9-1b. Confidence limits for Hill model fitted to 2,4,6-Trinitrotoluene concentrations and percent cover for pads 66/67. Solid curve is the fitted model. Dashed lines closest to model curve are 80% confidence limits of mean model prediction. The 90% and 95% confidence limits are further from the model, respectively. Triangles represent the individual measurements.

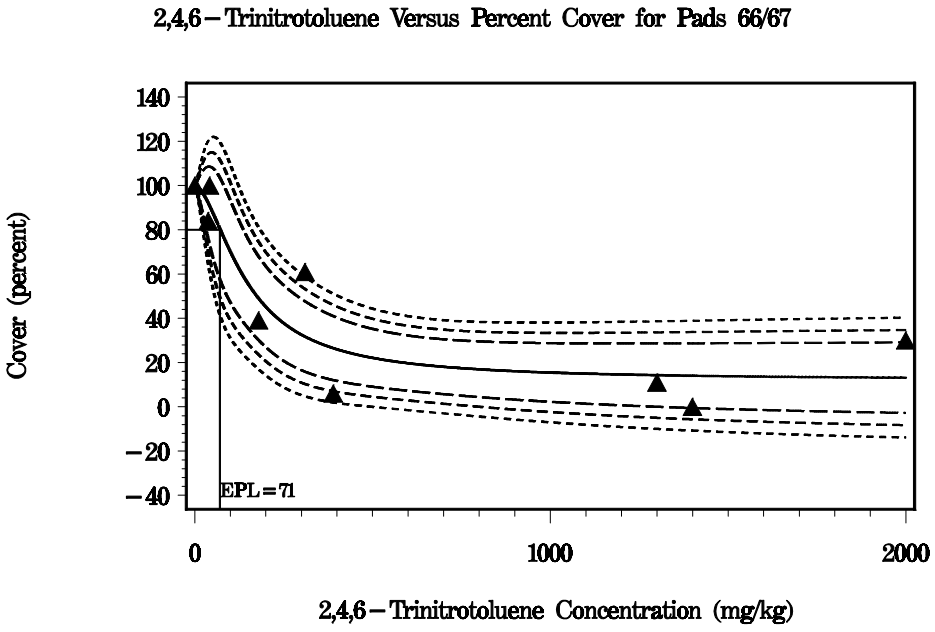

Figure 9-1c. EPL determination for 2,4,6-trinitrotoluene versus percent cover for pads 66/67. Solid curve is the fitted model. Dashed lines closest to model curve are 80% confidence limits of mean model prediction. The 90% and 95% confidence limits are further from the model, respectively. Horizontal and vertical solid lines show the EPL estimation. Triangles represent the individual measurements.

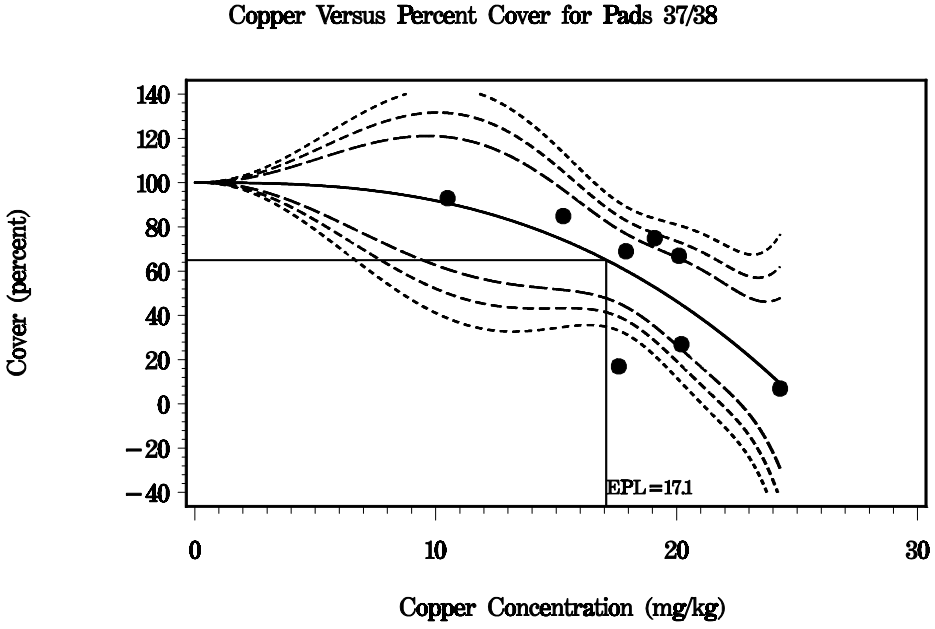

Figure 9-2. Copper versus percent cover for pads 37/38. Solid curve is the fitted model. Dashed lines closest to model curve are 80% confidence limits of mean model prediction. The 90% and 95% confidence limits are further from the model, respectively. Horizontal and vertical solid lines show the EPL estimation. Circles represent the individual measurements.

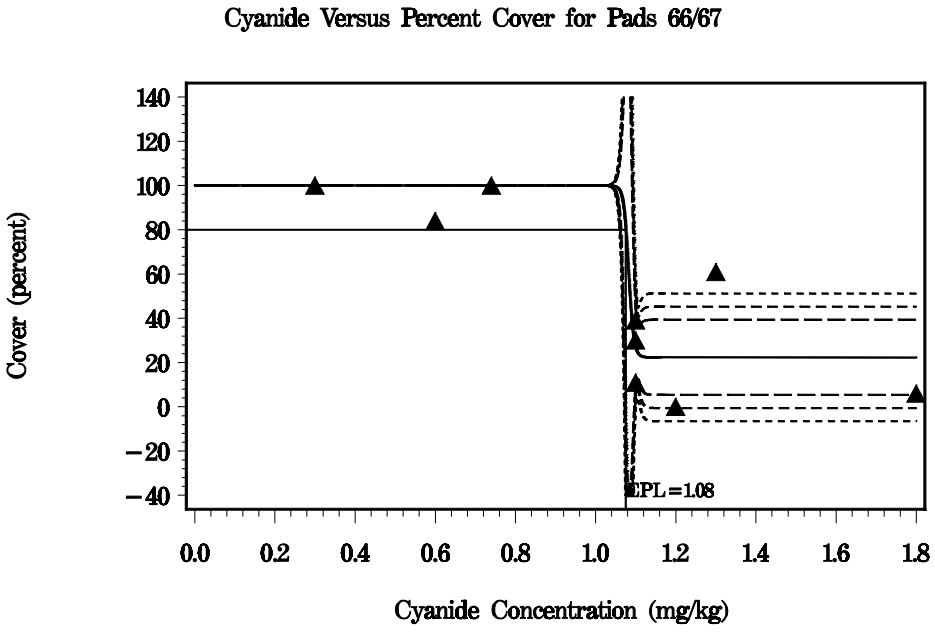

Figure 9-3. Cyanide versus percent cover for pads 66/67. Solid curve is the fitted model. Dashed lines closest to model curve are 80% confidence limits of mean model prediction. The 90% and 95% confidence limits are further from the model, respectively. Horizontal and vertical solid lines show the EPL estimation. Triangles represent the individual measurements.

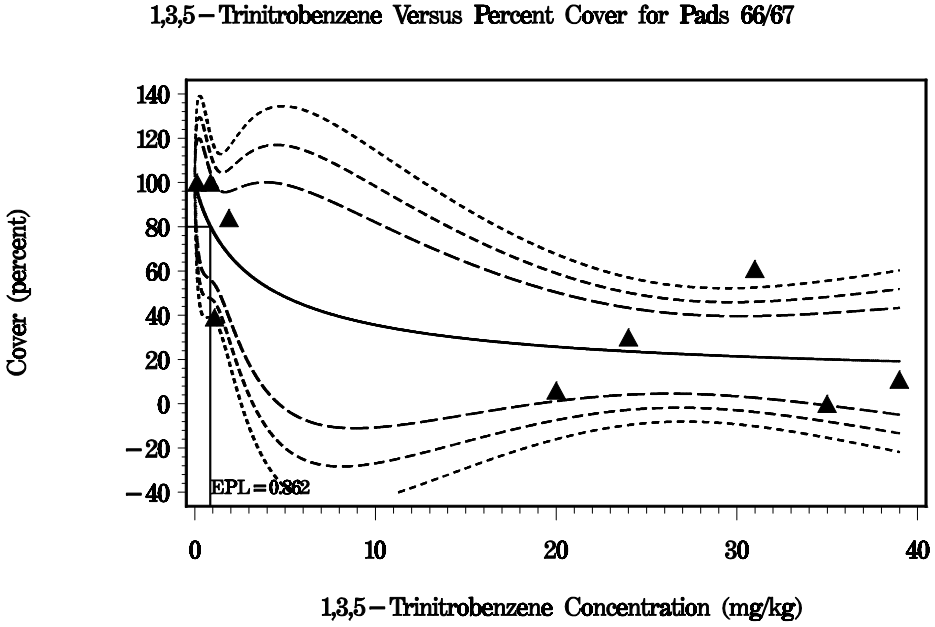

Figure 9-4. 1,3,5-Trinitrobenzene versus percent cover for pads 66/67. Solid curve is the fitted model. Dashed lines closest to model curve are 80% confidence limits of mean model prediction. The 90% and 95% confidence limits are further from the model, respectively. Horizontal and vertical solid lines show the EPL estimation. Triangles represent the individual measurements.

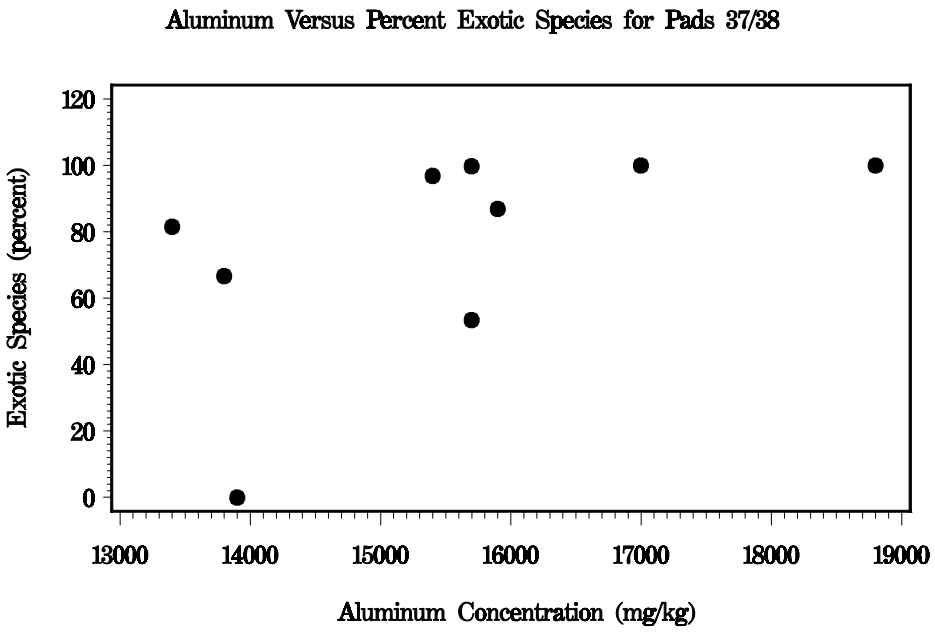

Figure 9-5. Aluminum versus percent exotic species for pads 37/38. Hill model could not be fit to the data.

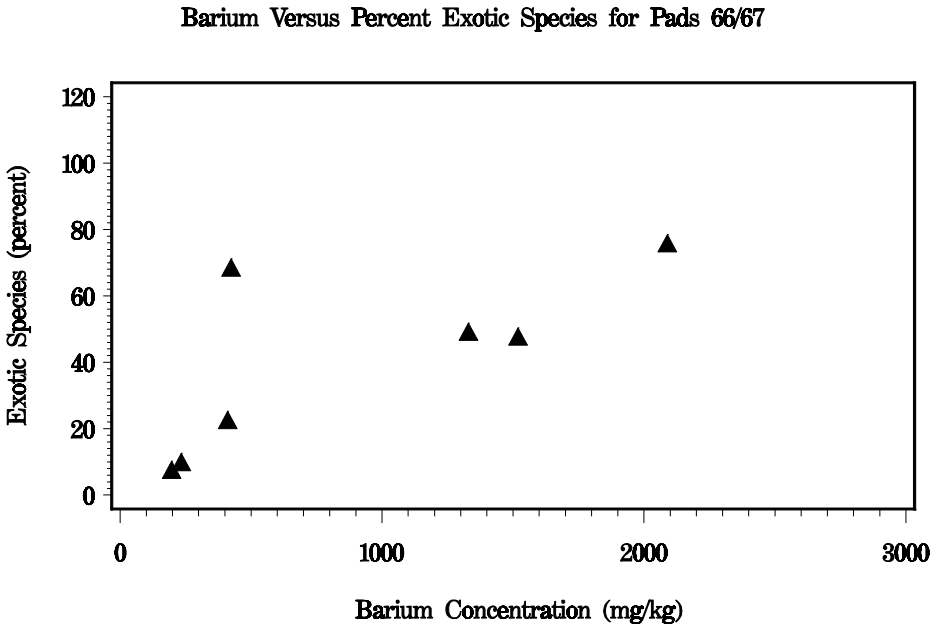

Figure 9-6. Barium versus percent exotic species for pads 66/67. Hill model could not be fit to the data.

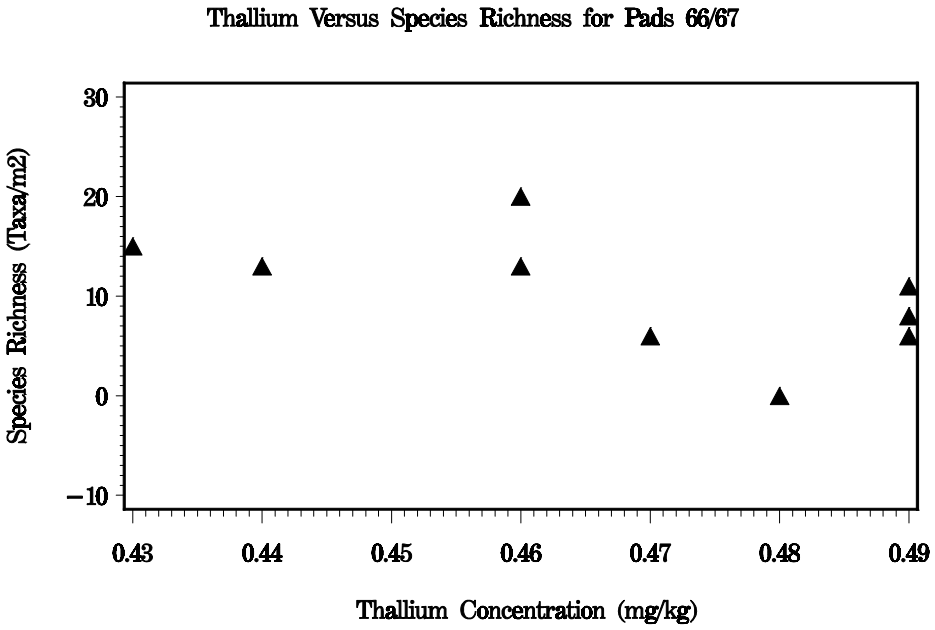

Figure 9-7. Thallium versus percent cover for pads 66/67. Hill model could not be fit to the data.

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TABLES

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Table 9-1. WBG Pad Pairs with Significant Spearman Rank Correlations Between Soil Concentrations and Vegetation Metrics[a]

COPECs (from WBG Phase II RI)	Percent Cover	Stems Density	Biomass	Species Richness	Percent Exotic Species	Diversity Index
Aluminum				+58/59	+37/38	
Arsenic	+66/67	+66/67	+66/67			
Barium					+66/67	
Cadmium					-37/38	+66/67
Chromium				+58/59		
Cobalt						
Copper	-37/38		+58/59	+58/59		
Cyanide	-66/67		+58/59			
Lead	+58/59			+58/59		
Manganese				+58/59		
Mercury	+37/38		+37/38			
Nickel						
Selenium					-66/67	
Silver			+58/59			
Thallium				-66/67		
Zinc			+58/59	+58/59		
HMX						
RDX						
1,3,5-Trinitrobenzene	-66/67				+66/67	
2,4,6-Trinitrotoluene	-66/67				+66/67	

[a]The direction of correlation is indicated by the sign before the pad pairs. A '+' indicates a positive correlation. A '-' indicates a negative correlation.

COPEC = contaminant of potential ecological concern.
RI = Remedial Investigation.
WBG = Winklepeck Burning Grounds.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

Table 9-2. Summary Statistics for Non-Linear Curve Fitting for PPL Determination

Analyte	Vegetation Metric	Pad Pair	Percent Variance Explained	Probability for Model Fit	PPL	PPL Lower 80% CL	PPL Lower 90% CL	PPL Lower 95% CL
Aluminum	Percent Exotic Species	37/38	NF	NF	NF	NF	NF	NF
Barium	Percent Exotic Species	66/67	NF	NF	NF	NF	NF	NF
Copper	Percent Cover	37/38	89	0.0079	13.9	6.41	5.45	4.81
Cyanide	Percent Cover	66/67	91	0.0002	1.08	1.06	1.06	1.06
Thallium	Species Richness	66/67	NF	NF	NF	NF	NF	NF
1,3,5-Trinitrobenzene	Percent Cover	66/67	86	0.0055	0.86	0.066	0.039	0.027
1,3,5-Trinitrobenzene	Percent Exotic Species	66/67	92	0.2251	NE	NE	NE	NE
2,4,6-Trinitrotoluene	Percent Cover	66/67	94	0.0005	71	31	25.4	21.8
2,4,6-Trinitrotoluene	Percent Exotic Species	66/67	93	0.0538	NE	NE	NE	NE

NF = Model could not be fit to the data.
NE = Plant protection levels (PPLs) and confidence limits could not be determined.

Table 9-3. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pad 37/38.

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	9/ 9	15500	1700	13400	18800	L	16700
Antimony	2/ 9	1.68	1.66	0.84	6.10	D	2.71
Arsenic	9/ 9	12.80	2.29	9.10	16.50	N	14.30
Barium	9/ 9	79.60	22.80	56.20	124	L	97.40
Beryllium	8/ 9	0.65	0.40	0.44	1.60	X	0.90
Cadmium	9/ 9	2.33	2.36	0.60	6.70	L	6.90
Calcium	9/ 9	15400	16600	2710	47500	L	56600
Chromium	9/ 9	17.50	2.05	14.40	20.20	L	19
Cobalt	9/ 9	8.30	1.46	6.70	10.60	L	9.39
Copper	9/ 9	70.70	158	10.50	491	X	168
Cyanide	2/ 9	0.84	0.74	0.71	2.80	D	1.30
Iron	9/ 9	26300	3940	19200	31800	N	28800
Lead	9/ 9	29.10	15.20	15	56.80	L	43.60
Magnesium	9/ 9	4360	1980	3010	8580	X	5580
Manganese	9/ 9	609	196	388	953	L	788
Mercury	9/ 9	0.04	0.01	0.03	0.05	N	0.04
Nickel	9/ 9	16	3.74	12.50	23.90	L	18.90
Potassium	9/ 9	1540	310	1150	2100	L	1780
Selenium	9/ 9	1.12	0.24	0.72	1.50	N	1.27
Sodium	8/ 9	222	199	59.30	507	L	637
Thallium	9/ 9	0.46	0.04	0.39	0.51	N	0.48
Vanadium	9/ 9	23.50	3.89	17.70	27.90	L	26.50
Zinc	9/ 9	110	91.10	51.40	346	L	184
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	2/ 9	0.28	0.13	0.15	0.62	D	0.36
1,3-Dinitrobenzene	1/ 9	0.23	0.05	0.09	0.09	D	0.27
2,4,6-Trinitrotoluene	6/ 9	67	192	0.06	580	X	186
2,4-Dinitrotoluene	3/ 9	0.22	0.06	0.06	0.21	D	0.26
4-Nitrotoluene	1/ 9	0.24	0.02	0.19	0.19	D	0.26
HMX	1/ 9	0.46	0.11	0.18	0.18	D	0.53
RDX	2/ 9	0.47	0.06	0.32	0.42	D	0.51
Other Organics (mg/kg)							
2,4-Dinitrotoluene	5/ 9	2.44	6.21	0.09	19	X	6.29
2,6-Dinitrotoluene	2/ 9	0.58	0.48	0.10	1.30	D	0.88
2-Methylnaphthalene	1/ 9	0.97	1.49	0.07	0.07	D	1.89
Di-n-butyl phthalate	5/ 9	3.57	8.46	0.08	26	L	94
N-Nitrosodiphenylamine	2/ 9	0.54	0.37	0.66	1.50	D	0.77
Phenanthrene	2/ 9	0.93	1.51	0.05	0.05	D	1.87

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-4. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pad 58/59

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	9/ 9	13100	3990	5920	20000	N	15600
Antimony	6/ 9	9.32	21	0.64	64.70	X	22.30
Arsenic	9/ 9	11.20	2.66	5.70	14.60	N	12.90
Barium	9/ 9	125	127	50.30	453	X	204
Beryllium	5/ 9	0.48	0.11	0.50	0.57	X	0.54
Cadmium	9/ 9	2.69	3.03	0.22	9.20	L	34
Calcium	9/ 9	11600	11000	1080	28600	L	100000
Chromium	9/ 9	21.30	10.10	8.80	41.60	L	31.80
Cobalt	9/ 9	11.70	4.21	8.40	21.70	X	14.30
Copper	9/ 9	100	166	9.60	526	L	640
Iron	9/ 9	24200	4410	13400	28700	X	26900
Lead	9/ 9	371	916	6.40	2800	L	33400
Magnesium	9/ 9	4110	1860	1700	7280	L	6340
Manganese	9/ 9	378	89.90	246	582	L	449
Mercury	9/ 9	0.06	0.05	0.02	0.17	L	0.11
Nickel	9/ 9	24.40	5.07	17.20	34.20	L	28.60
Potassium	9/ 9	1910	672	797	2950	N	2330
Selenium	9/ 9	1.33	0.46	0.53	2.10	N	1.62
Silver	4/ 9	1.62	1.80	0.61	6.40	D	2.74
Sodium	7/ 9	249	223	75.70	451	X	387
Thallium	9/ 9	0.45	0.05	0.34	0.51	N	0.49
Vanadium	9/ 9	20.60	5.62	8.80	29.20	N	24
Zinc	9/ 9	234	287	31.50	838	L	1390
Explosives (mg/kg)							
2,4,6-Trinitrotoluene	1/ 9	0.24	0.03	0.17	0.17	D	0.26
RDX	2/ 9	0.48	0.13	0.18	0.66	D	0.56
Other Organics (mg/kg)							
2-Methylnaphthalene	4/ 9	0.37	0.16	0.07	0.67	D	0.47
Benz(a)anthracene	1/ 9	0.35	0.10	0.09	0.09	D	0.41
Benzo(a)pyrene	2/ 9	0.32	0.13	0.04	0.14	D	0.40
Benzo(b)fluoranthene	2/ 9	0.33	0.12	0.05	0.20	D	0.40
Benzo(g,h,i)perylene	1/ 9	0.35	0.09	0.12	0.12	D	0.41
Benzo(k)fluoranthene	1/ 9	0.35	0.11	0.07	0.07	D	0.41
Bis(2-ethylhexyl)phthalate	2/ 9	0.33	0.11	0.13	0.14	D	0.39
Chrysene	1/ 9	0.35	0.09	0.11	0.11	D	0.41
Dibenzofuran	1/ 9	0.34	0.11	0.05	0.05	D	0.41
Fluoranthene	3/ 9	0.28	0.16	0.05	0.10	D	0.38
Indeno(1,2,3-cd)pyrene	1/ 9	0.36	0.08	0.14	0.14	D	0.41
Naphthalene	4/ 9	0.27	0.14	0.04	0.18	D	0.35
Phenanthrene	4/ 9	0.28	0.14	0.05	0.27	D	0.36
Pyrene	2/ 9	0.32	0.13	0.08	0.11	D	0.40

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-5. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pad 66/67

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	9/ 9	13100	1790	10600	16500	L	14400
Antimony	9/ 9	5.91	4.31	1.00	12.50	N	8.59
Arsenic	9/ 9	11.50	2.11	8.40	15.50	L	13.10
Barium	9/ 9	997	763	197	2090	L	3600
Beryllium	9/ 9	0.46	0.05	0.39	0.52	L	0.49
Cadmium	9/ 9	2.43	2.62	0.63	8.70	L	7.10
Calcium	9/ 9	7550	1900	4710	10000	N	8720
Chromium	9/ 9	19.50	2.71	15.50	24.30	N	21.20
Cobalt	9/ 9	6.92	1.14	4.90	8.40	N	7.63
Copper	9/ 9	115	83	31.60	269	L	262
Cyanide	8/ 9	1.06	0.38	0.60	1.80	N	1.30
Iron	9/ 9	24600	3550	18600	29600	N	26800
Lead	9/ 9	108	74.20	38.20	290	L	185
Magnesium	9/ 9	2980	409	2420	3480	L	3290
Manganese	9/ 9	715	85.40	578	888	L	777
Mercury	9/ 9	0.12	0.08	0.06	0.29	L	0.19
Nickel	9/ 9	15.30	1.51	13.30	17.70	L	16.40
Potassium	9/ 9	1410	220	877	1640	X	1550
Selenium	9/ 9	1.15	0.37	0.60	1.70	N	1.38
Silver	1/ 9	1.09	0.33	0.22	0.22	D	1.30
Sodium	7/ 9	228	216	88.60	178	X	362
Thallium	9/ 9	0.47	0.02	0.43	0.49	N	0.48
Vanadium	9/ 9	22.30	4.05	16.10	29.20	L	25.40
Zinc	9/ 9	245	163	83.70	624	L	432
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	7/ 8	19	16	0.89	39	N	29.70
1,3-Dinitrobenzene	3/ 9	0.19	0.10	0.04	0.07	D	0.25
2,4,6-Trinitrotoluene	9/ 9	629	739	0.32	2000	L	86500000
2,4-Dinitrotoluene	4/ 9	0.29	0.16	0.09	0.25	D	0.39
4-Nitrotoluene	1/ 9	0.24	0.03	0.17	0.17	D	0.26
HMX	9/ 9	115	119	0.36	370	N	189
RDX	9/ 9	730	810	0.19	2400	X	1230
Other Organics (mg/kg)							
2,4-Dinitrotoluene	3/ 5	1.09	0.72	0.26	1.50	N	1.78
2-Methylnaphthalene	1/ 9	3.13	1.47	0.05	0.05	D	4.04
Acenaphthene	1/ 9	3.15	1.42	0.22	0.22	D	4.03
Anthracene	1/ 9	3.22	1.26	0.87	0.87	D	4.00
Benz(a)anthracene	2/ 9	3.22	1.37	0.21	2.60	D	4.07
Benzo(a)pyrene	1/ 9	3.38	0.99	2.30	2.30	D	3.99
Benzo(b)fluoranthene	2/ 9	3.25	1.34	0.29	2.80	D	4.08
Benzo(g,h,i)perylene	1/ 9	3.24	1.21	1.10	1.10	D	4.00
Benzo(k)fluoranthene	1/ 9	3.24	1.21	1.10	1.10	D	4.00
Carbazole	1/ 9	3.17	1.37	0.41	0.41	D	4.02
Chrysene	1/ 9	3.38	0.99	2.30	2.30	D	3.99
Dibenz(a,h)anthracene	1/ 9	3.16	1.39	0.34	0.34	D	4.02
Dibenzofuran	1/ 9	3.14	1.43	0.19	0.19	D	4.03
Fluoranthene	3/ 9	3.17	1.76	0.35	5.30	D	4.26

Table 9-5. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pad 66/67 (continued)

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Fluorene	1/ 9	3.15	1.41	0.29	0.29	D	4.03
Indeno(1,2,3-cd)pyrene	1/ 9	3.28	1.15	1.40	1.40	D	3.99
Naphthalene	1/ 9	3.13	1.46	0.07	0.07	D	4.04
Phenanthrene	1/ 9	3.48	0.91	3.20	3.20	D	4.04
Pyrene	2/ 9	3.47	1.39	0.35	4.70	D	4.33

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-6. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pads 37/38, 58/59, and 66/67

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	27/ 27	13900	2850	5920	20000	N	14800
Antimony	17/ 27	5.64	12.3	0.64	64.7	X	9.69
Arsenic	27/ 27	11.9	2.38	5.7	16.5	N	12.6
Barium	27/ 27	400	608	50.3	2090	X	600
Beryllium	22/ 27	0.531	0.248	0.39	1.6	X	0.612
Cadmium	27/ 27	2.48	2.58	0.22	9.2	L	4.5
Calcium	27/ 27	11500	11600	1080	47500	L	18500
Chromium	27/ 27	19.4	6.09	8.8	41.6	X	21.4
Cobalt	27/ 27	8.99	3.28	4.9	21.7	L	9.97
Copper	27/ 27	95.2	136	9.6	526	X	140
Cyanide	10/ 27	0.827	0.501	0.6	2.8	D	0.992
Iron	27/ 27	25000	3940	13400	31800	N	26300
Lead	27/ 27	169	531	6.4	2800	X	343
Magnesium	27/ 27	3820	1640	1700	8580	X	4350
Manganese	27/ 27	567	192	246	953	N	630
Mercury	27/ 27	0.0723	0.0594	0.024	0.29	L	0.0922
Nickel	27/ 27	18.6	5.53	12.5	34.2	X	20.4
Potassium	27/ 27	1620	479	797	2950	L	1800
Selenium	27/ 27	1.2	0.369	0.53	2.1	N	1.32
Silver	5/ 27	1.3	1.04	0.22	6.4	D	1.64
Sodium	22/ 27	233	205	59.3	507	X	300
Thallium	27/ 27	0.46	0.039	0.34	0.51	X	0.473
Vanadium	27/ 27	22.1	4.57	8.8	29.2	N	23.6
Zinc	27/ 27	196	200	31.5	838	L	287
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	9/ 26	6.03	12.2	0.15	39	D	10.1
1,3-Dinitrobenzene	4/ 27	0.222	0.0683	0.042	0.088	D	0.245
2,4,6-Trinitrotoluene	16/ 27	232	512	0.061	2000	X	400
2,4-Dinitrotoluene	7/ 27	0.253	0.102	0.063	0.25	D	0.286
4-Nitrotoluene	2/ 27	0.245	0.0189	0.17	0.19	D	0.251
HMX	10/ 27	38.8	86	0.18	370	D	67
RDX	13/ 27	244	570	0.18	2400	D	431
Other Organics (mg/kg)							
2,4-Dinitrotoluene	8/ 23	1.34	3.88	0.09	19	D	2.73
2,6-Dinitrotoluene	2/ 27	1.38	1.52	0.1	1.3	D	1.88
2-Methylnaphthalene	6/ 27	1.49	1.68	0.051	0.67	D	2.04
Acenaphthene	1/ 27	1.51	1.66	0.22	0.22	D	2.05
Anthracene	1/ 27	1.53	1.64	0.87	0.87	D	2.07
Benz(a)anthracene	3/ 27	1.53	1.68	0.089	2.6	D	2.08
Benzo(a)pyrene	3/ 27	1.57	1.66	0.04	2.3	D	2.11
Benzo(b)fluoranthene	4/ 27	1.53	1.69	0.054	2.8	D	2.08
Benzo(g,h,i)perylene	2/ 27	1.53	1.65	0.12	1.1	D	2.07
Benzo(k)fluoranthene	2/ 27	1.53	1.65	0.065	1.1	D	2.07
Bis(2-ethylhexyl)phthalate	2/ 27	1.5	1.67	0.13	0.14	D	2.05
Carbazole	1/ 27	1.52	1.65	0.41	0.41	D	2.06
Chrysene	2/ 27	1.58	1.65	0.11	2.3	D	2.12

Table 9-6. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Co-Located with Vegetation Measurements at Pads 37/38, 58/59, and 66/67 (continued)

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Di-n-butyl phthalate	5/ 27	2.37	4.97	0.078	26	D	4
Dibenz(a,h)anthracene	1/ 27	1.52	1.65	0.34	0.34	D	2.06
Dibenzofuran	2/ 27	1.5	1.67	0.045	0.19	D	2.04
Fluoranthene	6/ 27	1.48	1.79	0.045	5.3	D	2.07
Fluorene	1/ 27	1.51	1.65	0.29	0.29	D	2.06
Indeno(1,2,3-cd)pyrene	2/ 27	1.55	1.64	0.14	1.4	D	2.09
N-Nitrosodiphenylamine	2/ 27	1.36	1.52	0.66	1.5	D	1.86
Naphthalene	5/ 27	1.47	1.69	0.041	0.18	D	2.02
Phenanthrene	7/ 27	1.56	1.72	0.052	3.2	D	2.12
Pyrene	4/ 27	1.6	1.78	0.075	4.7	D	2.18

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-7. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pad 37/38

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	11/ 11	15800	2780	12300	22200	L	17500
Antimony	2/ 8	1.74	1.76	0.84	6.10	D	2.92
Arsenic	11/ 11	12.50	3.19	7.10	17.70	N	14.20
Barium	11/ 11	142	161	56.20	596	X	230
Beryllium	7/ 8	0.68	0.42	0.44	1.60	L	1.12
Cadmium	11/ 11	87.40	263	0.58	877	X	231
Calcium	8/ 8	16000	17700	2710	47500	L	96600
Chromium	11/ 11	19.20	4.21	14.40	27.20	L	21.90
Cobalt	8/ 8	8.41	1.52	6.70	10.60	N	9.43
Copper	8/ 8	78.20	167.00	15.30	491.00	X	190.00
Cyanide	2/ 8	0.87	0.78	0.71	2.80	D	1.40
Iron	8/ 8	26100	4130	19200	31800	N	28800
Lead	11/ 11	99.60	149	18.80	504	X	181
Magnesium	8/ 8	4510	2060	3010	8580	X	5890
Manganese	11/ 11	799	562	351	2170	L	1230
Mercury	8/ 11	0.04	0.01	0.03	0.05	L	0.04
Nickel	8/ 8	16.50	3.74	12.90	23.90	L	19.60
Potassium	8/ 8	1560	329	1150	2100	L	1850
Selenium	11/ 11	1.42	1.21	0.62	5.00	X	2.08
Sodium	7/ 8	239	205	59.30	507	L	773
Thallium	8/ 8	0.46	0.04	0.39	0.51	N	0.49
Vanadium	8/ 8	22.90	3.76	17.70	27.90	L	26
Zinc	11/ 11	158	116	61.20	346	X	221
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	2/ 11	0.28	0.12	0.15	0.62	D	0.34
1,3-Dinitrobenzene	1/ 11	0.24	0.05	0.09	0.09	D	0.26
2,4,6-Trinitrotoluene	7/ 11	55.10	174	0.06	580	X	150
2,4-Dinitrotoluene	4/ 11	0.23	0.06	0.06	0.31	D	0.26
HMX	1/ 11	0.88	0.73	0.18	0.18	D	1.28
RDX	2/ 11	0.61	0.26	0.32	0.42	D	0.75
Other Organics (mg/kg)							
2,4-Dinitrotoluene	5/ 8	2.69	6.59	0.09	19	X	7.11
2,6-Dinitrotoluene	2/ 8	0.61	0.50	0.10	1.30	D	0.94
2-Methylnaphthalene	1/ 8	1.04	1.58	0.07	0.07	D	2.10
Di-n-butyl phthalate	5/ 8	3.97	8.95	0.08	26	L	319
N-Nitrosodiphenylamine	2/ 8	0.56	0.39	0.66	1.50	D	0.82
Phenanthrene	2/ 8	1.00	1.60	0.05	0.05	D	2.07
Chloroform	1/ 1	0.00		0.00	0.00	X	

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-8. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pad 58/59

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	16/ 16	12600	2990	7070	20000	L	14100
Antimony	11/ 13	8.00	17.50	0.64	64.70	L	29.90
Arsenic	16/ 16	13.40	3.83	7.40	23.50	L	15.30
Barium	16/ 16	124	97.60	43.10	453	L	167
Beryllium	7/ 13	0.52	0.12	0.43	0.71	N	0.57
Cadmium	16/ 16	7.94	19.60	0.36	80	L	24.90
Calcium	13/ 13	11100	9580	1830	28600	L	32400
Chromium	16/ 16	39.90	47.20	11.50	189	X	60.60
Cobalt	13/ 13	10.30	1.90	7.80	15.20	L	11.30
Copper	13/ 13	155	207	19.30	653	L	515
Iron	13/ 13	25500	2260	21500	29800	L	26700
Lead	16/ 16	377	719	11.60	2800	L	2600
Magnesium	13/ 13	4080	1510	2340	7280	L	5030
Manganese	16/ 16	411	100	177	582.00	N	455
Mercury	14/ 16	0.17	0.27	0.02	1.10	L	0.36
Nickel	13/ 13	26.90	4.95	18.50	35.90	L	29.70
Potassium	13/ 13	1870	557	1080	2950	L	2240
Selenium	10/ 16	1.09	0.49	0.98	2.10	N	1.30
Silver	11/ 16	2.01	2.12	0.22	6.40	X	2.94
Sodium	9/ 13	171	164	75.70	451	X	252
Thallium	9/ 13	0.54	0.15	0.34	0.53	L	0.62
Vanadium	13/ 13	21.10	3.66	15.10	29.20	L	23.20
Zinc	16/ 16	392	350	56.20	1040	X	546
Explosives (mg/kg)							
2,4,6-Trinitrotoluene	2/ 12	2.97	9.46	0.17	33	D	7.87
RDX	2/ 12	0.61	0.26	0.18	0.66	D	0.75
Other Organics (mg/kg)							
2-Methylnaphthalene	4/ 8	0.37	0.17	0.07	0.67	N	0.49
Benz(a)anthracene	1/ 8	0.35	0.10	0.09	0.09	D	0.42
Benzo(a)pyrene	2/ 8	0.31	0.14	0.04	0.14	D	0.40
Benzo(b)fluoranthene	2/ 8	0.32	0.13	0.05	0.20	D	0.40
Benzo(g,h,i)perylene	1/ 8	0.35	0.09	0.12	0.12	D	0.41
Benzo(k)fluoranthene	1/ 8	0.34	0.11	0.07	0.07	D	0.42
Bis(2-ethylhexyl)phthalate	2/ 8	0.32	0.11	0.13	0.14	D	0.40
Chrysene	1/ 8	0.35	0.10	0.11	0.11	D	0.41
Dibenzofuran	1/ 8	0.34	0.12	0.05	0.05	D	0.42
Fluoranthene	3/ 8	0.27	0.16	0.05	0.10	D	0.37
Indeno(1,2,3-cd)pyrene	1/ 8	0.35	0.09	0.14	0.14	D	0.41
Naphthalene	4/ 8	0.25	0.14	0.04	0.18	X	0.35
Phenanthrene	4/ 8	0.26	0.14	0.05	0.27	X	0.36
Pyrene	2/ 8	0.31	0.13	0.08	0.11	D	0.40

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.

[b]Population Distribution Codes:

D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.

HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-9. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pad 66/67

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	11/ 11	11900.00	2920.00	6330.00	16500.00	N	13500.00
Antimony	9/ 9	12.10	13.10	1.00	45.10	L	77.70
Arsenic	11/ 11	11.80	2.37	8.40	15.80	L	13.30
Barium	11/ 11	970.00	736.00	69.80	2090.00	N	1370.00
Beryllium	9/ 9	0.45	0.04	0.39	0.52	L	0.47
Cadmium	10/ 11	2.56	3.16	0.07	8.70	L	53.90
Calcium	9/ 9	7210.00	2690.00	3350.00	11700.00	N	8880.00
Chromium	11/ 11	18.40	4.92	7.00	24.30	N	21.10
Cobalt	9/ 9	6.76	1.09	4.90	8.40	N	7.43
Copper	9/ 9	213.00	261.00	47.80	876.00	L	703.00
Cyanide	6/ 7	1.12	0.39	0.74	1.80	L	1.59
Iron	9/ 9	24000.00	3750.00	18600.00	29600.00	L	26800.00
Lead	11/ 11	102.00	89.00	16.10	336.00	L	271.00
Magnesium	9/ 9	2770.00	394.00	2200.00	3480.00	L	3060.00
Manganese	11/ 11	635.00	206.00	165.00	888.00	N	748.00
Mercury	10/ 11	0.11	0.07	0.04	0.29	L	0.19
Nickel	9/ 9	14.90	1.64	12.70	17.30	L	16.10
Potassium	9/ 9	1430.00	339.00	877.00	1980.00	N	1640.00
Selenium	7/ 11	0.91	0.43	0.60	1.70	N	1.14
Silver	2/ 11	0.85	0.50	0.21	0.22	D	1.13
Sodium	5/ 9	258.00	206.00	88.60	178.00	L	584.00
Thallium	9/ 9	0.49	0.04	0.43	0.57	L	0.52
Vanadium	9/ 9	21.70	4.78	14.70	29.20	N	24.60
Zinc	11/ 11	327.00	393.00	36.20	1410.00	L	867.00
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	8/ 11	16.80	16.50	0.37	39.00	X	25.80
1,3-Dinitrobenzene	5/ 11	0.16	0.10	0.04	0.07	D	0.22
2,4,6-Trinitrotoluene	11/ 11	534.00	703.00	0.32	2000.00	X	919.00
2,4-Dinitrotoluene	4/ 11	0.33	0.21	0.09	0.25	D	0.44
2-Amino-4,6-dinitrotoluene	1/ 2	3.34	3.34	0.97	0.97	N	18.30
4-Nitrotoluene	1/ 11	0.24	0.02	0.17	0.17	D	0.26
HMX	9/ 11	64.60	75.00	0.36	230.00	L	33000.00
RDX	9/ 11	388.00	520.00	0.19	1700.00	X	673.00
Other Organics (mg/kg)							
2,4-Dinitrotoluene	3/ 4	0.89	0.65	0.26	1.50	L	423.00
2-Methylnaphthalene	1/ 7	3.19	1.59	0.05	0.05	D	4.36
Acenaphthene	1/ 7	3.22	1.53	0.22	0.22	D	4.34
Anthracene	1/ 7	3.31	1.32	0.87	0.87	D	4.28
Benz(a)anthracene	1/ 7	3.56	0.88	2.60	2.60	D	4.20
Benzo(a)pyrene	1/ 7	3.51	0.94	2.30	2.30	D	4.20
Benzo(b)fluoranthene	1/ 7	3.59	0.85	2.80	2.80	D	4.21
Benzo(g,h,i)perylene	1/ 7	3.34	1.25	1.10	1.10	D	4.26
Benzo(k)fluoranthene	1/ 7	3.34	1.25	1.10	1.10	D	4.26
Carbazole	1/ 7	3.24	1.47	0.41	0.41	D	4.32
Chrysene	1/ 7	3.51	0.94	2.30	2.30	D	4.20
Dibenz(a,h)anthracene	1/ 7	3.23	1.49	0.34	0.34	D	4.33

Table 9-9. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pad 66/67 (continued)

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Dibenzofuran	1/ 7	3.21	1.54	0.19	0.19	D	4.34
Fluoranthene	1/ 7	3.94	0.98	5.30	5.30	D	4.66
Fluorene	1/ 7	3.23	1.51	0.29	0.29	D	4.33
Indeno(1,2,3-cd)pyrene	1/ 7	3.39	1.17	1.40	1.40	D	4.24
Naphthalene	1/ 7	3.20	1.58	0.07	0.07	D	4.36
Phenanthrene	1/ 7	3.64	0.80	3.20	3.20	D	4.23
Pyrene	1/ 7	3.86	0.86	4.70	4.70	D	4.49

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

Table 9-10. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pads 36/37, 58/59, and 66/67

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Inorganics (mg/kg)							
Aluminum	38/ 38	13300	3270	6330	22200	N	14200
Antimony	22/ 30	7.56	13.80	0.64	64.70	X	11.80
Arsenic	38/ 38	12.70	3.26	7.10	23.50	L	13.60
Barium	38/ 38	374	553	43.10	2090	X	526
Beryllium	23/ 30	0.54	0.24	0.39	1.60	X	0.61
Cadmium	37/ 38	29.40	142	0.07	877	X	68.30
Calcium	30/ 30	11200	11300	1830	47500	L	16600
Chromium	38/ 38	27.70	32	7	189	X	36.50
Cobalt	30/ 30	8.73	2.17	4.90	15.20	L	9.51
Copper	30/ 30	152	214	15.30	876	X	218
Cyanide	8/ 27	0.81	0.50	0.71	2.80	D	0.98
Iron	30/ 30	25200	3290	18600	31800	N	26200
Lead	38/ 38	217	486	11.60	2800	X	350
Magnesium	30/ 30	3800	1590	2200	8580	X	4290
Manganese	38/ 38	588	358	165	2170	L	682
Mercury	32/ 38	0.11	0.18	0.02	1.10	X	0.16
Nickel	30/ 30	20.50	6.84	12.70	35.90	X	22.60
Potassium	30/ 30	1650	475	877	2950	L	1820
Selenium	28/ 38	1.13	0.77	0.60	5.00	L	1.34
Silver	13/ 38	1.36	1.50	0.21	6.40	D	1.77
Sodium	21/ 30	215	186	59.30	507	X	273
Thallium	26/ 30	0.50	0.11	0.34	0.57	X	0.54
Vanadium	30/ 30	21.80	3.98	14.70	29.20	L	23.10
Zinc	38/ 38	305	324	36.20	1410	L	448
Explosives (mg/kg)							
1,3,5-Trinitrobenzene	10/ 34	5.62	12	0.15	39	D	9.11
1,3-Dinitrobenzene	6/ 34	0.22	0.08	0.04	0.09	D	0.24
2,4,6-Trinitrotoluene	20/ 34	192	466	0.06	2000	X	327
2,4-Dinitrotoluene	8/ 34	0.27	0.13	0.06	0.31	D	0.31
2-Amino-4,6-dinitrotoluene	1/ 3	2.31	2.96	0.97	0.97	D	7.30
4-Nitrotoluene	1/ 34	0.25	0.01	0.17	0.17	D	0.25
HMX	10/ 34	21.50	51.20	0.18	230	D	36.40
RDX	13/ 34	126	341	0.18	1700	D	225
Other Organics (mg/kg)							
2,4-Dinitrotoluene	8/ 20	1.41	4.16	0.09	19	D	3.01
2,6-Dinitrotoluene	2/ 23	1.33	1.53	0.10	1.30	D	1.88
2-Methylnaphthalene	6/ 23	1.46	1.71	0.05	0.67	D	2.08
Acenaphthene	1/ 23	1.49	1.69	0.22	0.22	D	2.09
Anthracene	1/ 23	1.52	1.67	0.87	0.87	D	2.12
Benz(a)anthracene	2/ 23	1.58	1.69	0.09	2.60	D	2.19
Benzo(a)pyrene	3/ 23	1.55	1.70	0.04	2.30	D	2.16
Benzo(b)fluoranthene	3/ 23	1.58	1.71	0.05	2.80	D	2.19
Benzo(g,h,i)perylene	2/ 23	1.51	1.68	0.12	1.10	D	2.12
Benzo(k)fluoranthene	2/ 23	1.51	1.68	0.07	1.10	D	2.11

Table 9-10. Upper 95% Confidence Limit of the Mean for Concentrations of Chemicals Detected in Surface Soil Samples Taken Inside the Vegetation Sampling Grid and Inside the Pad Boundaries for Pads 36/37, 58/59, and 66/67 (continued)

Analyte	Results > Detection Limit	Average Result[a]	Standard Deviation	Minimum Detect	Maximum Detect	Dist.[b]	95% UCL of Mean
Bis(2-ethylhexyl)phthalate	2/ 23	1.47	1.70	0.13	0.14	D	2.08
Carbazole	1/ 23	1.50	1.69	0.41	0.41	D	2.10
Chrysene	2/ 23	1.57	1.69	0.11	2.30	D	2.17
Di-n-butyl phthalate	5/ 23	2.50	5.36	0.08	26	D	4.42
Dibenz(a,h)anthracene	1/ 23	1.49	1.69	0.34	0.34	D	2.10
Dibenzofuran	2/ 23	1.47	1.70	0.05	0.19	D	2.08
Fluoranthene	4/ 23	1.67	1.88	0.05	5.30	D	2.34
Fluorene	1/ 23	1.49	1.69	0.29	0.29	D	2.10
Indeno(1,2,3-cd)pyrene	2/ 23	1.53	1.68	0.14	1.40	D	2.13
N-Nitrosodiphenylamine	2/ 23	1.32	1.53	0.66	1.50	D	1.86
Naphthalene	5/ 23	1.44	1.73	0.04	0.18	D	2.06
Phenanthrene	7/ 23	1.55	1.76	0.05	3.20	D	2.18
Pyrene	3/ 23	1.66	1.81	0.08	4.70	D	2.31
Chloroform	1/ 1	0.00		0.00	0.00	X	

[a]Nondetects were included in the calculated statistics at one-half the reported detection limit.
[b]Population Distribution Codes:
D = Fewer than 50% detects (t-distribution for UCL).
L = Log-normal distribution (Land statistic for UCL).
N = Normal distribution (t-distribution for UCL).
X = Significantly different from normal and log-normal. Use arithmetic mean and t-distribution for 95% UCL.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.

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