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Resource Conservation and Recovery Act Corrective Measures Study Report for SWMU 9 - Pesticide Control/R-150 Tank Area

Naval Surface Warfare Center
Crane, Indiana

NAVFAC
Naval Facilities Engineering Command

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
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RESOURCE CONSERVATION AND RECOVERY ACT CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NAVAL SURFACE WARFARE CENTER CRANE, INDIANA

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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TABLE OF CONTENTS

SECTION **PAGE NO.**

ACRONYMS **4**

1.0 INTRODUCTION **1-1**
1.1 SCOPE AND OBJECTIVES 1-1
1.2 ORGANIZATION OF CORRECTIVE MEASURES STUDY 1-2
1.3 ACTIVITY BACKGROUND INFORMATION 1-2
1.3.1 Facility Location 1-2
1.3.2 Facility History 1-3
1.3.3 Project Site 1-4
1.4 PHYSICAL CHARACTERISTICS OF STUDY AREA 1-7
1.4.1 Climate and Meteorology 1-8
1.4.2 Topography 1-8
1.4.3 Surface Water Hydrology 1-9
1.4.4 Geology and Soils 1-9
1.4.5 Hydrogeology 1-10
1.4.6 Water Supply 1-11
1.4.7 Surrounding Land Use 1-11
1.4.8 Ecological Setting 1-11

2.0 DESCRIPTION OF CURRENT CONDITIONS **2-1**
2.1 NATURE AND EXTENT OF CONTAMINATION 2-1
2.1.1 Surface Soil 2-1
2.1.2 Subsurface Soil 2-4
2.1.3 Groundwater 2-7
2.1.4 Surface Water 2-10
2.1.5 Sediment 2-12
2.2 CONTAMINANT FATE AND TRANSPORT 2-15
2.3 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS 2-17
2.3.1 Human Health Risk Assessment 2-17
2.3.2 Ecological Risk Assessment 2-18

3.0 DEVELOPMENT OF CORRECTIVE MEASURES OBJECTIVES **3-1**
3.1 ARARs 3-1
3.1.1 Contaminant-Specific ARARs and TBC Criteria 3-2
3.1.2. Location-Specific ARARs and TBC Criteria 3-4
3.1.3 Action-Specific ARARs and TBC Criteria 3-8
3.2 MEDIUM-SPECIFIC CORRECTIVE ACTION OBJECTIVES 3-10
3.2.1 Soils 3-10
3.2.2 Ground Water 3-11
3.3 CHEMICALS OF CONCERN 3-11
3.3.1 Ground Water 3-11
3.4 MEDIA CLEANUP STANDARDS 3-11
3.4.1 Ground Water 3-11
3.5 VOLUME OF CONTAMINATED MEDIA 3-13
3.5.1 Ground Water 3-13

TABLE OF CONTENTS (Continued)

SECTION **PAGE NO.**

4.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES 4-1
4.1 PRELIMINARY SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES 4-1
4.2 DETAILED SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES 4-1
4.2.1 No Action 4-2
4.2.2 Limited Action 4-3
4.3 SELECTION OF CORRECTIVE MEASURES TECHNOLOGIES AND PROCESS OPTIONS 4-6
4.3.1 Alternative 1: No Action 4-6
4.3.2 Alternative 2: Monitored Natural Attenuation, Institutional Controls, and Monitoring 4-7

5.0 EVALUATION OF THE CORRECTIVE MEASURES ALTERNATIVES 5-1
5.1 ALTERNATIVE 1: NO ACTION 5-1
5.1.1 Protection of Human Health and the Environment 5-1
5.1.2 Attainment of MCSs 5-2
5.1.3 Source Control 5-2
5.1.4 Compliance with Waste Management Standards 5-2
5.1.5 Other Factors 5-2
5.2 ALTERNATIVE 2 – INSTITUTIONAL CONTROLS, MONITORING, AND MNA 5-3
5.2.1 Protection of Human Health and the Environment 5-3
5.2.2 Attainment of MCSs 5-3
5.2.3 Source Control 5-3
5.2.4 Compliance with Waste Management Standards 5-4
5.2.5 Other Factors 5-4

6.0 COMPARATIVE ANALYSIS AND RECOMMENDATION 6-1
6.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT 6-1
6.2 ATTAINMENT OF MCSs 6-1
6.3 SOURCE CONTROL 6-1
6.4 COMPLIANCE WITH WASTE MANAGEMENT STANDARDS 6-1
6.5 OTHER FACTORS 6-2
6.5.1 Long-Term Reliability and Effectiveness 6-2
6.5.2 Reduction in Toxicity, Mobility, and Volume 6-2
6.5.3 Short-Term Effectiveness 6-2
6.5.4 Implementability 6-2
6.5.5 Cost 6-3
6.5.6 State and Community Acceptance 6-3
6.6 RECOMMENDED CORRECTIVE MEASURE 6-3

REFERENCES R-1

APPENDIX

A ALTERNATE 2 COST ESTIMATE

TABLES

NUMBER

1-1 Climatological Mean Monthly Temperatures
1-2 Climatological Mean Monthly Rainfall and Snowfall Amounts
2-1 Summary of Positive Analytical Results, COPCs, and Risk Drivers for Surface Soil
2-2 Summary of Positive Analytical Results, COPCs, and Risk Drivers for Subsurface Soil
2-3 Summary of Positive Analytical Results, COPCs, and Risk Drivers for Groundwater
2-4 Summary of Positive Analytical Results, COPCs, and Risk Drivers for Surface Water
2-5 Summary of Positive Analytical Results, COPCs, and Risk Drivers for Surface Water
2-6 Summary of Risk Drivers for Groundwater
3-1 Summary of Contaminant-Specific ARARs and TBC Criteria
3-2 Summary of Location-Specific ARARs and TBCs
3-3 Summary of Action-Specific ARARs and TBC Criteria
3-4 Summary of Receptor-Specific Human Risks, and Hazards and Ecological Risks, and Recommendations
3-5 Human Health Media Cleanup Standards
4-1 Preliminary Screening of Ground Water Remediation Technologies and Process Options
6-1 Summary of Comparative Analysis of Corrective Measures Alternatives

FIGURES

NUMBER

1-1 General Location Map
1-2 Site Features and Sample Location Map
1-3 Site Location and Surface Drainage
1-4 Surficial Geology and Depositional Environments
1-5 Cross Section Location Map
1-6 Geologic Cross Section A-A'
1-7 Geologic Cross Section B-B'
1-8 Geologic Cross Section C-C'
1-9 Potentiometric Surface Map (1-10-01)
2-1 Organic Detections in Surface Soil
2-2 Inorganic Detections in Surface Soil
2-3 Organic Detections in Subsurface Soil
2-4 Inorganic Detections in Subsurface Soil
2-5 Inorganic and Organic Detections in Groundwater
2-6 Inorganic and Organic Detections in Surrace Water
2-7 Inorganic and Organic Detections in Sediment

ACRONYMS

§	Part
§§	Parts
°F	degrees Fahrenheit
µg/kg	microgram per kilogram
µg/L	microgram per liter
AHPA	Archaeological and Historic Preservation Act
ALPEC	Ammunition Loading and Production Engineering Center
ARAR	Applicable or Relevant and Appropriate Requirement
BAF	bioaccumulation factor
BGEPA	Bald and Gold Eagle Protection Act
bgs	below ground surface
CAA	Clean Air Act
CAAA	Crane Army Ammunition Activity
CAO	Corrective Action Objective
CASCO	Central Ammunition Supply Control Office
CEC	cation exchange capacity
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CMA	Corrective Measures Alternative
CMD	Corrective Measures Design
CMS	Corrective Measures Study
COPC	chemicals of potential concern
CTO	Contract Task Order
CWA	Clean Water Act
DCA	1,1-dichloroethane
DCE	1,1-dichlororethene
DO	Dissolved oxygen
DOT	Department of Transportation
EEQ	Ecological Effects Quotient
EO	Executive Order
FWCA	Fish and Wildlife Coordination Act
g	gram
HI	Hazard Indices

HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
IA	Installation Assessment
IAAQS	Indiana Ambient Air Quality Standards
IAS	Initial Assessment Study
IASLs	Indiana Air Screening Levels
IDEM	Indiana Department of Environmental Management
IERA	Indiana Environmental Remediation Act
IESA	Indiana Non-game and Endangered Species Conservation Act
ILCR	Incremental lifetime cancer risk
in/hr	inches per hour
in/yr	inches per year
IR	Installation Restoration
IRIS	Integrated Risk Information System
ISM	Interim Stabilization Measure
ISWMB	Indiana Solid Waste Management Board
IWPCB	Indiana Water Pollution Control Board
IWQS	Indiana Water Quality Standard
IWR	Indiana Wildlife Regulation
kg	kilogram
LDRs	Land Disposal Restriction
LOAEL	lowest-observed-adverse effect level
LUC	Land use control
MCLG	Maximum Contaminant Level Goal
MCL	Maximum Contaminant Level
MCS	Media Cleanup Standard
meq	milliequivalents
MF	modifying factor
mg	milligram
mg/kg	millgram per kilogram
mg/L	milligram per liter
MNA	Monitored natural attenuation
mph	miles per hour
NAAQS	National Ambient Air Quality Standards
NAD	Naval Ammunition Depot
NAVFAC EFD SOUTH	Naval Facilities Engineering Field Division South

NCP	National Contingency Plan
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOAEL	no-observed-adverse effect level
NPDES	National Pollutant Discharge Elimination System
NSWC	Naval Surface Warfare Center
NWSCC	Naval Weapons Support Center Crane
O&M	Operation and maintenance
ORP	Oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCE	tetrachloroethene
PEL	permissible exposure limit
PID	Photoionization Detector
PPE	Personal protective equipment
PRG	Preliminary Remediation Goals
RAO	Remedial Action Objectives
RBCs	Risk-Based Concentrations
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RfD	Reference Dose
RISC	Risk Integrated System of Closure
SDWA	Safe Drinking Water Act
SMCL	Secondary MCL
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
SWMU 10	Rockeye
SWMU 4	McComish Gorge
SWMU 5	Old Burn Pit
SWMU 9	Pesticide Control/R-150 Tank Area
TAL	Target Analyte List
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TBC	To Be Considered

TCE	Trichloroethene
TCR	target cancer risk
THI	Target Hazard Index
TOC	total organic carbon
TRV	Toxicity Reference Value
TSCA	Toxic Substance Control Act
TSD	treatment, storage, or disposal
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper Confidence Limit
U.S. EPA	United States Environmental Protection Agency
UF	uncertainty factor
U.S.	United States
USACE WES	United States Army Corps of Engineers Waterways Experimental Station
VOC	volatile organic compound

1.0 INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) Report was prepared by Tetra Tech NUS, Inc. (TtNUS) for Solid Waste Management Unit (SWMU) 9, Pesticide Control/R-150 Tank Area, at the Naval Surface Warfare Center (NSWC) facility located in Crane, Indiana, through the United States Navy Naval Facilities Engineering Field Division South (NAVFAC EFD SOUTH) under Contract Task Order (CTO) 0256 for the Comprehensive Long-Term Environmental Action Navy (CLEAN) 3, Contract Number N62467-94-D-0888.

This work is part of the Navy's Installation Restoration (IR) Program, which is designed to identify contamination of Navy and Marine Corps lands/facilities resulting from past operations and to institute corrective measures, as needed. There are typically four distinct IR phases. Phase 1 is the Preliminary Assessment [formerly known as the Initial Assessment Study (IAS)]. Phase 2 is a RCRA Facility Assessment (RFA), which augments the information collected in the Preliminary Assessment. Phase 3 is the RCRA Facility Investigation (RFI)/CMS which characterizes the contamination at a facility and develops options for remediation of the site. Phase 4 is the Corrective Measure Implementation which results in the control or cleanup of contamination at sites. This report has been prepared under Phase 3 (RFI/CMS). The Indiana Department of Environmental Management (IDEM) is the lead oversight agency. However, under a work-sharing agreement, United States Environmental Protection Agency (U.S. EPA) Region 5 is responsible for all phases of the RFI/CMS at SWMU 9.

This work was conducted in accordance with the requirements of the Indiana State RCRA Hazardous Waste Permit for the facility (IN5170023498), effective on January 13, 2000.

The corrective measure action and objectives of the CMS are as follows:

- Identify Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) criteria.

- Identify risk-based action levels that are protective of human health and the environment.

- Develop Corrective Action Objectives (CAO), which identify chemicals of concern, receptors, pathways, and preliminary remediation goals. The preliminary remediation goals are based on chemical-specific ARARs, TBCs, and risk-based action levels.

- Identify and screen corrective measures technologies.

- Develop Corrective Measures Alternatives (CMAs).

- Conduct a detailed analysis of CMAs.

An RFI Report for SWMUs 4 (McComish Gorge), 5 (Old Burn Pit), 9 (Pesticide Control/R-150 Tank Area), and 10 (Rockeye) at NSWC Crane presents the findings of the human health and ecological risk assessments conducted for SWMU 9 (TtNUS, 2004).

1.2 ORGANIZATION OF CORRECTIVE MEASURES STUDY

The CMS consists of six sections. Section 1.0 is this introduction. Section 2.0 provides a description of the current situation for SWMU 9. Section 3.0 identifies the ARARs, TBCs, and corrective measure objectives for SWMU 9. Section 4.0 provides the identification and screening of corrective measure technologies for each medium (soil, groundwater, etc.) at SWMU 9. Sections 5.0 and 6.0 present the development and evaluation/comparative analysis of CMAs, respectively.

1.3 ACTIVITY BACKGROUND INFORMATION

1.3.1 Facility Location

NSWC Crane is located in the southern portion of Indiana, approximately 75 miles southwest of Indianapolis and 71 miles northwest of Louisville, Kentucky, immediately east of Crane Village and Burns City (Figure 1-1). NSWC Crane encompasses 62,463 acres (approximately 98 square miles), most of which are located in the northern portion of Martin County. Smaller portions are located in Greene, Daviess, and Lawrence Counties. NSWC Crane is located in a rural, sparsely populated area. Most of NSWC Crane is forested, and the surrounding area is wooded or farmed land.

NSWC Crane provides naval support for equipment, shipboard weapons systems, and ordnance. In addition, NSWC Crane supports the Crane Army Ammunition Activity (CAAA) with production and renovation of conventional ammunition and storage, shipment, demilitarization, and disposal of conventional ammunition.

1.3.2 Facility History

This section provides general information on the history of NSWC Crane and its activities.

1.3.2.1 History of Ownership and Operation

In 1940, Congress authorized construction of a Naval Ammunition Depot (NAD) in southern Indiana; NAD Burns City was commissioned late in 1941. In 1943, NAD Burns City was renamed NAD Crane, and the Town of Crane was built to house the rapidly growing number of civil service employees. NAD Crane's overall mission was to load, prepare, renovate, receive, store, and issue ammunition to the fleet.

During World War II, NAD Crane's mission expanded to include pyrotechnics production, mine filling, rocket assembly, field storage, torpedo storage, and ordnance spare parts and mobile equipment storage. During the 1950s, several new departments were created, the Ammunition Loading and Production Engineering Center (ALPEC) was transferred to NSWC Crane, and the Central Ammunition Supply Control Office (CASCO) was established. NAD Crane supplied ammunition to the fleet during the Korean and Vietnam Conflicts. During the Vietnam Conflict, the number of full-time employees at NAD Crane grew to 6,800.

In 1975, NAD Crane was redesignated Naval Weapons Support Center Crane (NWSCC). Its new mission was to provide support for ships, aircraft, equipment, shipboard weapons systems, and assigned ordnance items and to perform additional functions as directed.

In 1977, the Single Manager Concept was implemented, the CAAA was created, and the Army assumed ordnance production, storage, and related responsibilities as a tenant organization. Other functions remained under Navy control, and currently the Navy retains ownership of all real estate and facilities at NSWC Crane. Responsibility for overall station safety, security, and environmental protection remains with the Commanding Officer, NSWC Crane. In 1992, the Facility was designated as NSWC Crane. Currently, approximately 4,000 people are employed at NSWC Crane.

1.3.2.2 History of Regulatory Actions

Following promulgation of the U.S. EPA RCRA hazardous waste regulatory program, NSWC Crane filed notification and application to operate as a RCRA hazardous waste treatment, storage, or disposal (TSD) facility in October 1980. Interim status was granted subject to operating requirements and applicable technical standards found in Title 40 of the Code of Federal Regulations (CFR), Part 265.

Corrective action programs established as part of the 1984 RCRA Hazardous and Solid Waste Amendments (HSWA) required NSWC Crane to address past releases of hazardous waste or hazardous constituents at SWMUs. Accordingly, NSWC Crane submitted a Hazardous Waste Management Report, and an RFA was conducted to characterize the potential for releases of hazardous waste or constituents from 100 SWMUs identified during the RFI assessment.

On December 23, 1989, U.S. EPA issued the federal portion of the Final RCRA Part B permit for NSWC Crane to the Navy. U.S. EPA renewed the permit in 1995. IDEM now has responsibility for the Federal Corrective Action Program. IDEM renewed the Corrective Action Permit in October 18, 2001. However, ongoing corrective actions will continue under the U.S. EPA IDEM Work Sharing Agreement for Corrective Action Activities at the Naval Surface Warfare Center - Crane Division.

1.3.3 Project Site

1.3.3.1 Site Description

Pesticide control activities were conducted at SWMU 9 from the 1950s through the early 1980s. These activities consisted of the storage and management of various types and quantities of pesticides and herbicides.

SWMU 9 consisted of three distinct areas: Building 55, Building 2189, and the R-150 Tank area. Pesticide control activities occurred at now demolished Buildings 55 and 2189. Waste solvents were stored in the R-150 Tank area; the tank has been removed from the site. The three areas were located near each other in a triangular configuration (see Figure 1-2). Building 2189 was located approximately 1,150 feet north of Building 55. The R-150 Tank area is located approximately 800 feet southwest of former Building 2189 and 700 feet northwest of former Building 55.

The original pesticide control operations were located in the northwest corner of Building 55 towards the boiler house (Building 150). In the late 1950s, pesticide control operations were moved from Building 55 to Building 2189. Pesticide spray tanks and containers were reportedly rinsed in the area west of Building 2189. It is not known whether rinsing activities occurred outside Building 55.

Pesticides and herbicides stored at Building 55 included, but were not limited to, 2,4-D, 2,4,5-T, silvex, fenac, monuron, ureabor, carbaryl, chlordane, DDT, diazinon, dieldrin, lindane, malathion, and pyrethrum.

In addition, when pesticide control operations were moved from Building 55 to Building 2189, the pesticide krovar (a mixture of diuron and bromac) was added to the chemical inventory for Building 2189.

Pesticides control operations ceased at the site around 1974, and Buildings 55 and 2189 have since been demolished. The concrete pad for Building 55 is still visible though crumbling. The concrete pad for Building 2189 is still present.

The R-150 Tank, which was located in a gravel parking lot adjacent to Highway 349, was installed at the site in the early 1970s and was used for the storage of spent waste solvents. The tank was 11 feet wide by 35 feet long, and the base of the tank was reportedly 15 feet deep. The tank was excavated and removed on September 27 and 28, 1983. During the tank removal, soil surrounding the tank excavation was removed and stockpiled at the site. The excavated soil was disposed in an offsite secure landfill in December 1983.

1.3.3.2 Land Usage

Under current land use, SWMU 9 is inactive and no waste disposal activities occur at this site. If SWMU 9 is re-activated, the future land use is expected to be limited to industrial uses.

1.3.3.3 Corrective Action Stages

The RFA has been completed. An RFI report has been submitted. No interim measures are required.

1.3.3.4 Interim/Stabilization Measures

No Interim/Stabilization Measures (ISMs) have been implemented at SWMU 9 since 1994. However, the 1983 tank removal/soil excavation would qualify as an ISM if it had been performed today.

1.3.3.5 Site Investigations

The following is a brief description of the historical data collection activities conducted at SWMU 9.

Various investigations were completed at the site from 1981 to 1987 as part of several multi-site investigations. The first of which was the Initial Assessment Study (IAS) (NEESA, 1983).

The IAS at SWMU 9 included the installation of a total of 14 monitoring wells throughout the site. The first round of installation in 1981 consisted of nine wells. Five monitoring wells were installed at various

locations (upgradient, downgradient, and cross-gradient) to address the R-150 Tank. Four monitoring wells were installed at locations downgradient (west) of Building 2189 to evaluate the impacts of pesticide operations at the building. During the installation of these wells, soil samples were collected and tested for various soil characteristics. Groundwater samples collected from the wells were analyzed for a comprehensive list of chemical constituents and RCRA water quality parameters.

In July 1983, four core borings (WT-1 through WT-4) were drilled on each side of the R-150 Tank. Water and soil samples were collected from the boreholes. The analytical results for these samples indicated that the tank had leaked and that hazardous constituents [volatile organic compounds (VOCs)] had been released to the surrounding environment. The tank was subsequently excavated and removed from the site in September 1983.

To better delineate the groundwater plume at the R-150 Tank area, five monitoring wells were installed around and downgradient of the tank in 1983. Upon groundwater well installation, samples were collected and analyzed for a comprehensive list of constituents. The wells were then added to the quarterly and semi-annual sampling programs initiated at the Pesticide Control/ R-150 Tank Area as part of the IAS.

Based on the initial conclusions of the IAS, it was determined that SWMU 9 did not present an immediate human health and environmental threat. However, the site was recommended for further study to evaluate potential long-term impacts.

In 1986, seven monitoring wells were installed around the R-150 Tank as part of the Groundwater Assessment Plan for tank closure (May and Murphy, 1989). Four wells were located in a circle around the tank, and one well was installed directly within the area where the tank was situated prior to excavation. Two wells were placed at locations upgradient of the tank. Groundwater samples were collected and analyzed for various constituents.

In response to the recommendation presented in the IAS, an RFI Phase II Soil Release Characterization was performed at the Pesticide Control/R-150 Tank Area in 1992 (U.S. ACE WES, 1988). The objective of the study was to determine soil conditions at the site and to identify and characterize hazardous constituents released to the surrounding environment. Fifteen soil borings were installed at the site. Both surface and subsurface samples were collected at each boring and analyzed for a comprehensive analytical program.

In 1992, a draft Work Plan for an RFI Groundwater Release Characterization was prepared by United States Army Corps of Engineers Waterways Experimental Station (U.S. ACE WES) (1995). The objective of the sampling effort was to determine the extent of hazardous constituents present in the groundwater, as well as the rate of migration. The proposed groundwater study included the collection of samples from the existing 20 monitoring wells at the site, plus the installation of additional wells.

Because of funding constraints, only a portion of the work proposed in the plan was conducted in 1992. Additional proposed monitoring wells were not installed and not all groundwater samples collected were analyzed for all proposed chemical constituents or for the same list of constituents. A Groundwater Release Characterization Report was not generated for the sampling effort because of funding issues.

Between November 13, 2000 and February 20, 2001, a field investigation was conducted to collect field and laboratory data to evaluate the potential risks for human and ecological receptors in support of an RFI for SWMU 9. The environmental samples collected from the site were analyzed under a comprehensive field and laboratory analytical program. Field parameters were collected for groundwater and surface water samples. Typical water quality indicator parameters, such as turbidity, were collected in the field. Soil samples were screened for VOCs using monitoring equipment [Photoionization Detector (PID)].

The most recent investigation was the Phase III RFI (TtNUS, 2004). The objectives of this investigation were as follows:

- To estimate the nature and extent of contamination.
- To develop information necessary to conduct baseline human health risk assessments and screening level ecological risk assessments.

1.4 PHYSICAL CHARACTERISTICS OF STUDY AREA

SWMU 9 is located in the central portion of NSWC Crane, approximately 5 miles northeast of the Burns City Gate No. 2. The site (including space between the three distinct areas) occupies approximately 11 acres. Site operations were centered around the three areas (Building 55, Building 2189, and the R-150 Tank Area) previously identified. The site is bounded on the east by Highway 45. Figure 1-2 shows these details for SWMU 9.

1.4.1 Climate and Meteorology

The climate in the region of NSWC Crane can be described as temperate (NOAA, 1988). Precipitation is distributed evenly throughout the year, and there is no pronounced wet or dry season for this region. Rainfall in the spring and summer is produced mostly from showers and thunderstorms. A peak rainfall of about 2-½ inches in a 24-hour period can be expected about once a year. Snowfalls of 3 inches or more occur on an average of two or three times per winter season.

Mean monthly temperatures for the region are shown in Table 1-1. Temperatures range from a minimum of 27.9°F in January to a maximum of 75.7°F in July. The mean annual temperature for the area is 52.6°F. The annual mean monthly distribution of rain and snow for the area is shown in Table 1-2. Annual rainfall total is about 40 inches per year (in/yr) with the highest mean monthly totals occurring in the late spring and in the early summer period of May through July. Snowfall averages about 23 inches a year, with most occurring in the winter months of December through February.

Long-term climatological records (NOAA, 1988) for the area indicate that the monthly prevailing wind direction is southwest during the month of April through December, then shifts to the northwest during the months of January through March. The annual prevailing wind direction for the region is from the southwest. The annual average wind speed for the area is about 9.6 miles per hour (mph).

1.4.2 Topography

1.4.2.1 NSWC Crane

NSWC Crane is in the unglaciated area of the Crawford Uplands Physiographic Province. This province is a rugged, highly vegetated, dissected plateau bounded by the Mitchell Plain Physiographic Province to the east and the Wabash Lowland Physiographic Province to the west (Murphy and Wade, 1998). The Mitchell Plain is a low dissected limestone plateau characterized by sinkholes and karst topographic features. The boundary between the Crawford Upland and the Mitchell Plain is marked by the highly irregular, eastern facing Chester Escarpment. Springs, caverns, caves, and other solution weathering features can be found along this escarpment and on the eastern edge of the NSWC Crane facility. The boundary between the Crawford Upland and the Mitchell Plain near the western boundary of NSWC Crane is gradual (Murphy and Wade, 1998).

The terrain is predominantly rolling with moderately incised stream valleys throughout and occasional flat areas in the central and northern portions of NSWC Crane. Most of the region is covered by deciduous trees and shrubs. The elevations across NSWC Crane range from about 500 feet above mean sea level

(AMSL) at the southern drainageway to about 850 feet AMSL on the ridge in the west-central portion of the site. V-shaped drainageways in the north progress to 2,000-foot-wide floodplains in the south and rise to approximately 150 to 200 feet to the ridgelines (NEESA, 1983).

1.4.2.2 SWMU 9 Pesticide Control/R-150 Tank Area

The topography at the site consists of undulating terrain dissected by many small drainageways. SWMU 9 lies along a northwestward slope. A road and railroad form a topographic high ridge that runs north-south along eastern border of SWMU 9.

1.4.3 Surface Water Hydrology

1.4.3.1 NSWC Crane

Six creeks receive drainage in five separate drainage basins at NSWC Crane (Figure 1-3). The six creeks are: Furst Creek, Sulphur Creek, Little Sulphur Creek, Boggs Creek, Turkey Creek, and Seed Tick Creek. Surface drainage from NSWC Crane eventually empties into the east fork of White River, south of the facility. Situated within NSWC Crane are Lake Greenwood and several ponds. Lake Greenwood is the main source of water at NSWC Crane and is also used for recreation (NEESA, 1983).

1.4.3.2 SWMU 9

Surface water east of the topographic high ridge that runs north-south, along the eastern border of SWMU 9 flows to the east through several drainage ditches that join to form a stream that flows south. Surface water runoff west of this ridge in the northern portion of SWMU 9 flows northwest into a stream. This stream conveys water in a southwest direction away from northern area of SWMU 9. A drainage ditch that originates from the former tank area flows west and discharges into this stream. Surface water runoff in the southern portion of SWMU 9 is also toward the west into a stream that flows south and southwest away from SWMU 9 area. This stream ultimately joins with the stream that conveys surface water from the northern portion of SWMU 9, further to the southwest. Both of these streams flow intermittently in their upstream reaches. These streams ultimately discharge into Boggs Creek.

1.4.4 Geology and Soils

1.4.4.1 NSWC Crane

NSWC Crane is located in the eastern flank Illinois Basin. Beneath unconsolidated colluvial and alluvial deposits, Paleozoic-age sedimentary rocks underlying NSWC Crane have been deformed to yield a

gentle dip of 50 feet per mile towards the west-southwest. The bedrock surface at NSWC Crane is made up of Lower Pennsylvanian- and Upper Mississippian-age sandstones, limestones, and shales.

In general, Mississippian-age Chester Series sandstones, shales, and limestones are exposed in the valley walls of eastern portions of NSWC Crane and in the lower elevations of deep valleys in the western portions. Pennsylvanian-age Mansfield Formation sandstone, siltstones, claystones, and shales are found at the crests of hills and ridges in eastern portions of NSWC Crane, and as the surficial bedrock unit further west (see Figure 1-4). The contact between the Mississippian units and overlaying Pennsylvanian units is an unconformity formed by long-time erosion of the Mississippian surface (Murphy and Ciocco, 1990).

Four soil units have been mapped at NSWC Crane (McElrath, G., Jr, 1988), including Wellston-Gilpin, Wellston-Berks-Gilpin, Wellston-Berks-Ebal, and Wakeland-Wilbur-Haymond Soils. These soils are primarily silt loams with permeabilities ranging from 0.6 to 2.0 inches per hour (in/hr) (Murphy, W.L, 1994).

1.4.4.2 SWMU 9

SWMU 9 is underlain by up to 10 feet of unconsolidated natural material overlying Pennsylvanian age sedimentary rocks of the Raccoon Creek Group Mansfield Formation. Soils mapped at the unit are representative of residual soils derived from the Pennsylvanian bedrock.

Three geologic cross-sections have been developed for SWMU 9 at locations shown on Figure 1-5 and are included on Figures 1-6, 1-7, and 1-8. The encountered subsurface materials included natural unconsolidated materials and bedrock. The natural unconsolidated materials are extensive across the SWMU 9 area and consist primarily of silt and clay. Bedrock was encountered at depths as shallow as 5 feet below ground surface (bgs) and consists primarily of sandstone with lenses of siltstone, shale, and coal.

1.4.5 Hydrogeology

Groundwater is present beneath the Facility in both the natural unconsolidated materials and the bedrock. The depth to groundwater ranges from less than 5 feet bgs in topographic low areas near surface water bodies to approaching 25 feet bgs at the higher elevations. The majority of the monitoring wells at the site were completed within the first groundwater yielding unit encountered during drilling, which existed in either the natural unconsolidated material or the shallow bedrock. The groundwater moves through the unconsolidated material or in fractures in the shallow bedrock and appears to be hydraulically connected.

This shallow groundwater system flows generally west and southwest as shown on Figure 1-6 toward the stream valleys which serve as groundwater discharge points. The shallow groundwater flows at an approximate gradient of 0.08. One of the previously installed wells (0914A, see Figure 1-9) was installed deeper in the bedrock in an interbedded shale and sandstone. This well was found to contain no groundwater during the synoptic water level measurement activity performed by TtNUS. A shale unit was also encountered less than 10 feet beneath the ground in this boring. It may be possible that shallow groundwater becomes perched on the shale and other lower permeable units that act as localized aquitards within the bedrock; therefore, limiting the vertical hydraulic connection in the bedrock.

1.4.6 Water Supply

Lake Greenwood, an 800-acre man-made, spring-fed lake in the northwestern portion of the installation is the main source of drinking water at NSWC Crane and it is also used for recreation. Groundwater at SWMU 9 is not currently and will not be used in the future as a potable drinking water source.

1.4.7 Surrounding Land Use

NSWC Crane is situated in a rural area of south-central Indiana. The surrounding communities that form the region are in a period of transition from an economic base of agriculture, mining, and quarrying to an economy built on manufacturing and service industries. The patterns of settlement, population statistics, and median income are similar throughout the region.

There is no state or local planning within the vicinity of NSWC Crane. The only zoning and land use regulations are found in the municipalities within the region. None of these municipalities are close enough to have an impact on NSWC Crane. None of the areas adjacent to NSWC Crane are zoned, and zoning is not anticipated in the near future. SWMU 9 is approximately 3 miles east of the nearest NSWC Crane property boundary; and is bounded on the east by Highway 45. There are no known current or likely future land use or community actions under consideration or proposed at this time for the SWMU 9 area. SWMU 9 is contained completely within NSWC Crane and likely future land use at areas surrounding the SWMU is expected to be limited to industrial uses.

1.4.8 Ecological Setting

1.4.8.1 Facility

A biological characterization of NSWC Crane, including a listing of plants and animals found at the facility, was presented in the Installation Assessment (IA) (Army, 1978) and the IAS (NEESA, 1983), and is

summarized in the Environmental Monitoring Reports (Halliburton NUS, 1992a and 1992b). A list of the species that may inhabit NSWC Crane and are protected under the U.S. Endangered Species Act, Indiana Department of Natural Resources Heritage Data Center, or the U.S. Fish and Wildlife Service is summarized in the RCRA Facility Permit (U.S. EPA, 1995). The following paragraphs briefly summarize the environmental setting at the installation.

Eighty percent of NSWC Crane's 63,000 acres are classified as Central Hardwoods Forest of the United States (NEESA, 1983). In addition, some agricultural fields are in various stages of succession. Openings on dry upland sites contain almost pure stands of grasses with some clumps of woody plants such as persimmon, sassafras, and sumac. Wetter sites have river birch, willow, sycamore, and cottonwood. Hillside communities have mostly hickory, white and black oak, red maple, sugar maple, tulip poplar, ash, and beech (NEESA, 1983).

The great variety of habitats at NSWC Crane (i.e., many stages of forest succession, streams, ponds, Lake Greenwood, grassy open spaces) has lead to a high diversity of animal species (NEESA, 1983). Some of these species include, but are not limited to, mammals such as white-tailed deer, beaver, coyote, hawks, red fox, rabbits, raccoons, mice; birds such as ducks, geese, wild turkey, bobwhite quail, red-tailed hawks, and American robins; and various amphibians, reptiles, fish, and invertebrates.

The bird population includes a number of state or federal threatened, endangered, or species of special concern that use the site as their home range. These species include the bald eagle, osprey, sharp-shinned hawk, red-shouldered hawk, broad-winged hawk, black and white warbler, hooded warbler, and the worm-eating warbler (B&R, 1997). Also, the Indiana bat, a federal endangered species, is known to forage at NSWC Crane. During a mist net and radiotelemetry survey conducted for NSWC Crane, a male Indiana bat was captured along Furst Creek, which is approximately 1.5 miles west of SWMU 10. No Indiana bats were captured near SWMU 5. Because of the bat and its potential habitat, the cutting of trees is restricted to certain times during the year, and the cutting of shagbark hickory trees is prohibited.

1.4.8.2 SWMU 9

SWMU 9 has been stocked with locust trees in the past. Other trees near this site include white ash (Fraxinus americana), largetooth aspen (Populus grandidentata), black cherry (Prunus serotina), black gum (Nyssa sylvatica), pignut hickory (Carya spp.), shagbark hickory (Carya spp.), black locust (Robinia pseudoacacia), sugar maple (Acer saccharum), red maple (Acer rubrum), black oak (Quercus velutina), chestnut and red oak (Quercus spp.), scarlet oak (Quercus coccinea), shingle oak (Quercus imbricaria), white oak (Quercus alba), persimmon (Diospyros virginiana), Virginia pine (Pinus virginiana), yellow

poplar (Liriodendron tuliplfera), redbud (Cercis canadensis), sassafras (Sassafras albidum), and black walnut (Juglans nigra).

TABLE 1-1

CLIMATOLOGICAL
MEAN MONTHLY TEMPERATURES[1]
SWMU 9 - PESTICIDE CONTROL AEA/R-150 TANK AREA
NSWC CRANE,
CRANE, INDIANA

Month	Mean Monthly Temperature (°F)
January	27.9
February	30.6
March	40.3
April	52.0
May	62.5
June	71.7
July	75.7
August	73.6
September	66.8
October	55.3
November	42.0
December	31.8
Mean Annual	52.6

1 Reference: NOAA, 1988.
°F - degrees Fahrenheit

TABLE 1-2

CLIMATOLOGICAL MEAN MONTHLY RAINFALL AND SNOWFALL AMOUNTS[1]
SWMU 9 - PESTICIDE CONTROL AREA/R-150 TANK AREA
NSWC CRANE, CRANE, INDIANA

Month	Mean Monthly Rainfall (inches)	Mean Monthly Snowfall (inches)
January	2.89	6.3
February	2.52	5.9
March	3.78	3.5
April	3.66	0.5
May	3.93	T[1]
June	4.06	0
July	3.89	0
August	3.28	0
September	3.11	0
October	2.68	T[2]
November	3.21	1.9
December	2.95	4.8
Annual	39.98	23.0

1 Reference: NOAA, 1988.
2 Indicates snowfall amounts less than 0.01 inch.

DRAWN BY J. LAMEY	DATE 3/9/00	GENERAL LOCATION MAP CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/ R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1-1 / REV 0

NAVFAC

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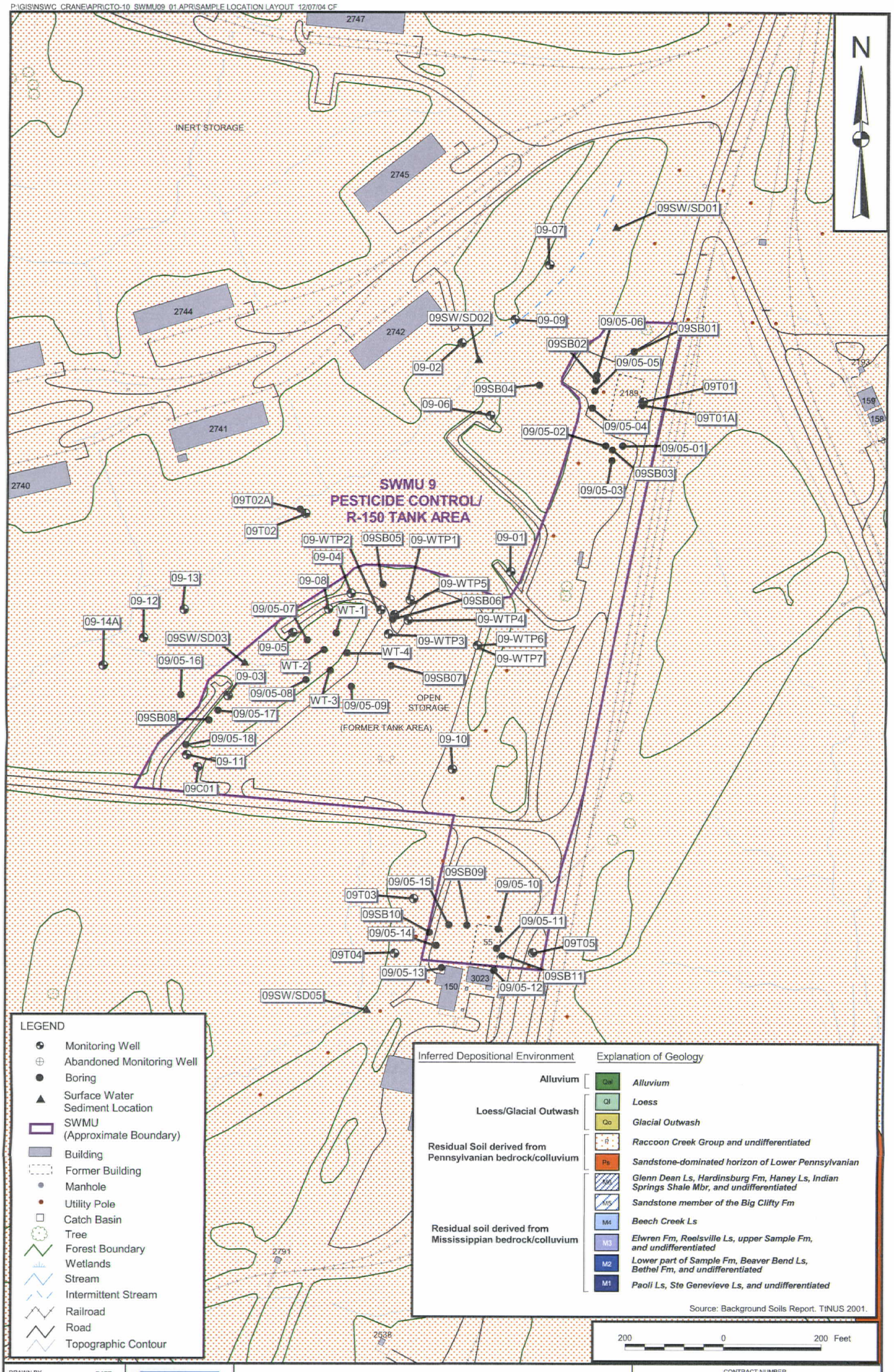

DRAWN BY K. PEILA	DATE 5/21/02	SITE FEATURES AND SAMPLE LOCATION MAP CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		DRAWING NO. FIGURE 1 - 2 / REV 0

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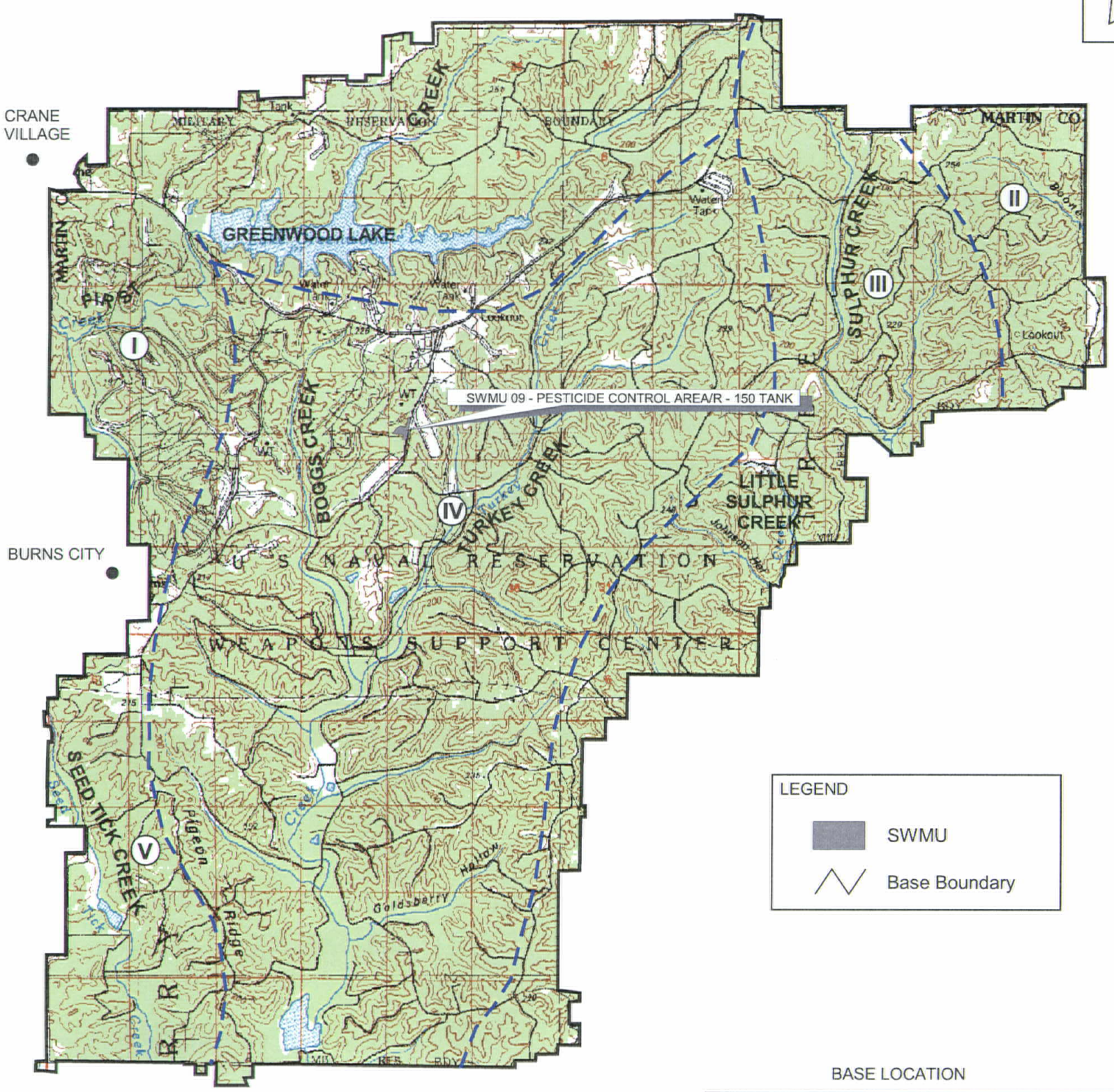

BASE LOCATION

MAJOR SURFACE DRAINAGE BASINS

I FURST CREEK DRAINAGE BASIN

II INDIAN CREEK DRAINAGE BASIN

III SULPHUR CREEK COMPLEX DRAINAGE BASIN

IV BOGGS & TURKEY CREEK DRAINAGE BASIN

V SEED TICK DRAINAGE BASIN

SOURCE: "Initial Assessment Study of Naval Weapons Support Center Crane, Indiana." Naval Energy and Environment Support Activity, May 1983.

DRAWN BY J. LAMEY	DATE 4/19/99	SITE LOCATION AND SURFACE DRAINAGE CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		DRAWING NO. FIGURE 1 - 3 REV 0

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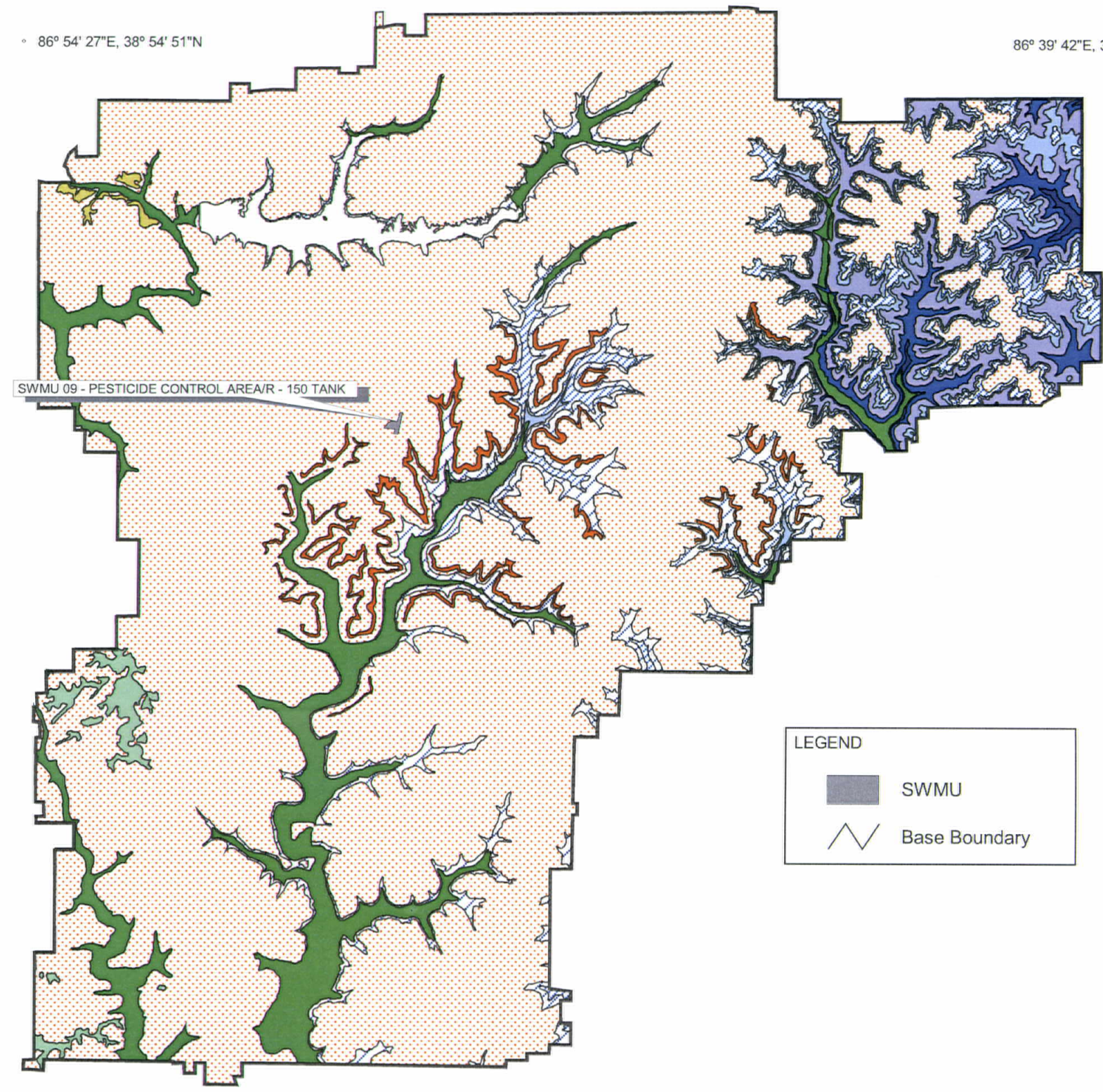

Inferred Depositional Environment		Explanation of Geology
Alluvium	Qal	*Alluvium*
Loess/Glacial Outwash	Ql	*Loess*
	Qo	*Glacial Outwash*
Residual Soil derived from Pennsylvanian bedrock/colluvium	P	*Raccoon Creek Group and undifferentiated*
	Ps	*Sandstone-dominated horizon of Lower Pennsylvanian*
Residual soil derived from Mississippian bedrock/colluvium	M6	*Glenn Dean Ls, Hardinsburg Fm, Haney Ls, Indian Springs Shale Mbr, and undifferentiated*
	M5	*Sandstone member of the Big Clifty Fm*
	M4	*Beech Creek Ls*
	M3	*Elwren Fm, Reelsville Ls, upper Sample Fm, and undifferentiated*
	M2	*Lower part of Sample Fm, Beaver Bend Ls, Bethel Fm, and undifferentiated*
	M1	*Paoli Ls, Ste Genevieve Ls, and undifferentiated*

Source: Background Soils Report. TtNUS 2001. (Modified from Blunck, 1995).

1.5 0 1.5 3 Miles

DRAWN BY D. PERRY	DATE 3/15/99	SURFICIAL GEOLOGY AND DEPOSITIONAL ENVIRONMENTS CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		DRAWING NO. FIGURE 1 - 4 REV 0

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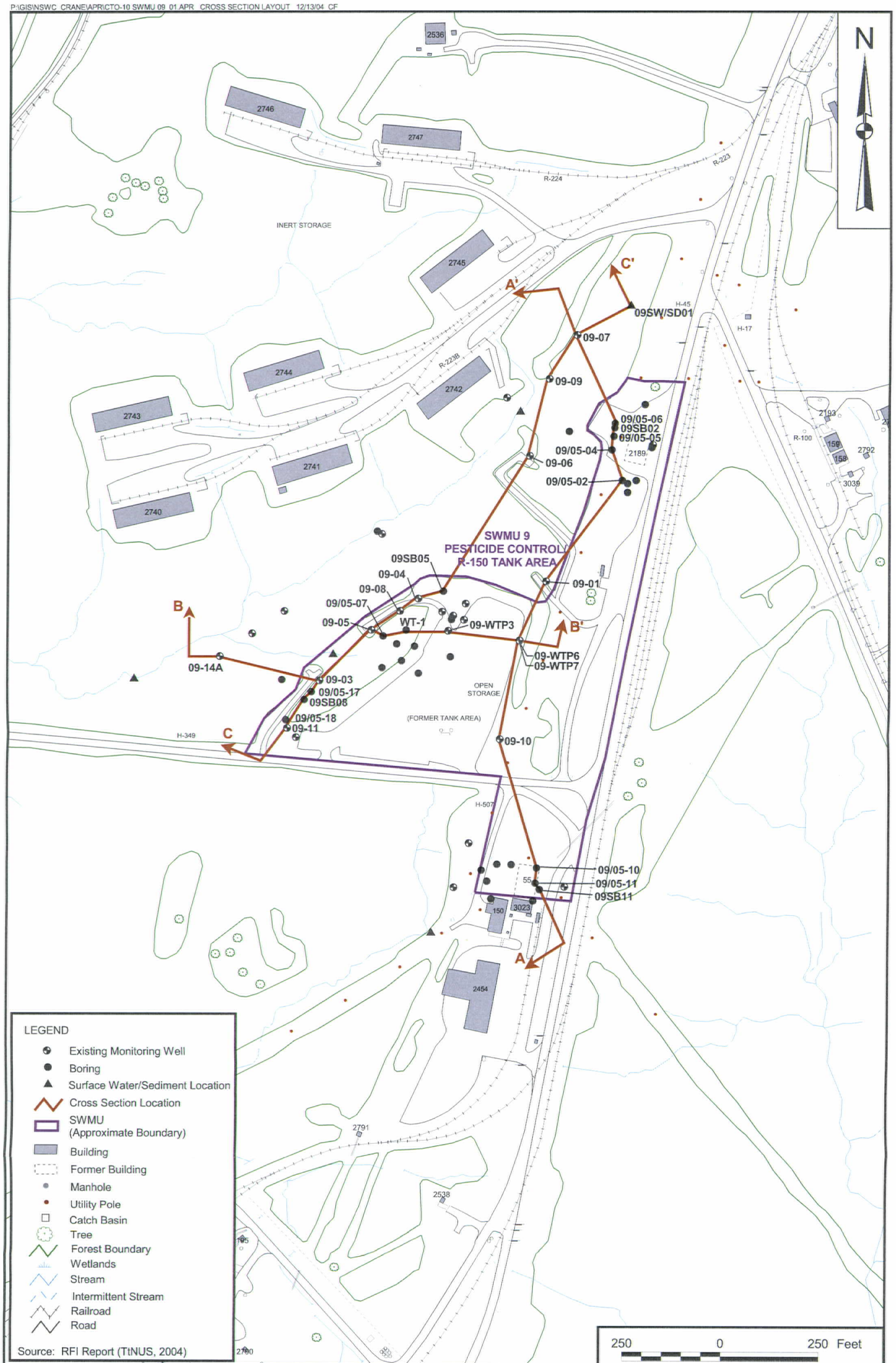
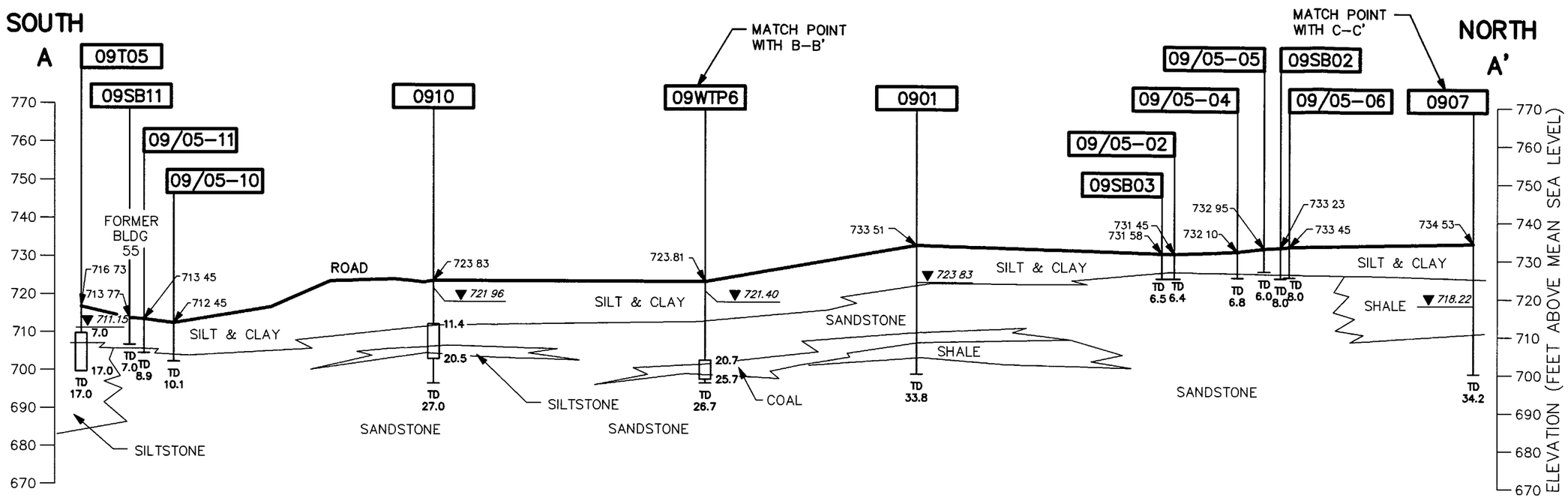


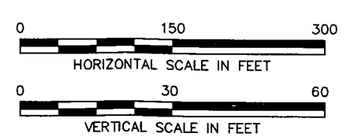
LEGEND

- Existing Monitoring Well
- Boring
- Surface Water/Sediment Location
- Cross Section Location
- SWMU (Approximate Boundary)
- Building
- Former Building
- Manhole
- Utility Pole
- Catch Basin
- Tree
- Forest Boundary
- Wetlands
- Stream
- Intermittent Stream
- Railroad
- Road

Source: RFI Report (TtNUS, 2004)

DRAWN BY K. PEILA	DATE 5/21/02	CROSS SECTION LOCATION MAP CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		DRAWING NO. FIGURE 1 - 5 REV 0





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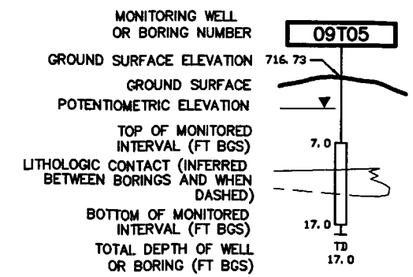

CONTRACT NO. 4267
OWNER NO. 0000
APPROVED BY
DATE
REV. 0
DRAWING NO. FIGURE 1-6

GEOLOGIC CROSS SECTION A-A'
CMS REPORT FOR
SWMU 9 - PESTICIDE CONTROL/
R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

NAVFAC

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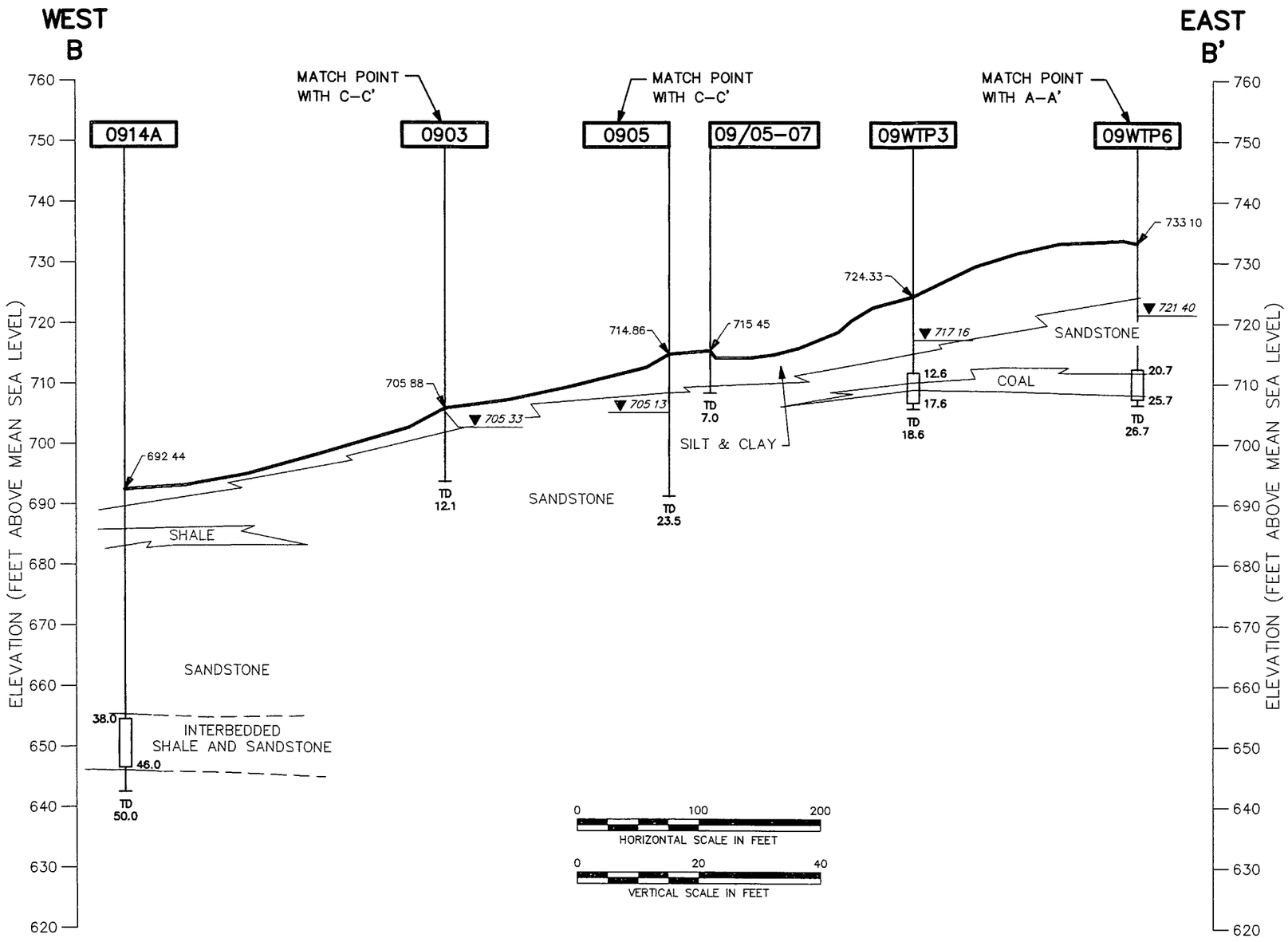

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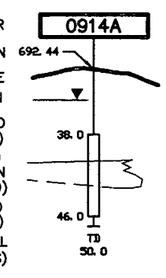

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OWNER NO. 0000
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DATE
DRAWING NO. FIGURE 1-7
REV. 0

GEOLOGIC CROSS SECTION B-B'
CMS REPORT FOR
SWMU 9 - PESTICIDE CONTROL/
R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

NAVFAC

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DATE 11/9/04
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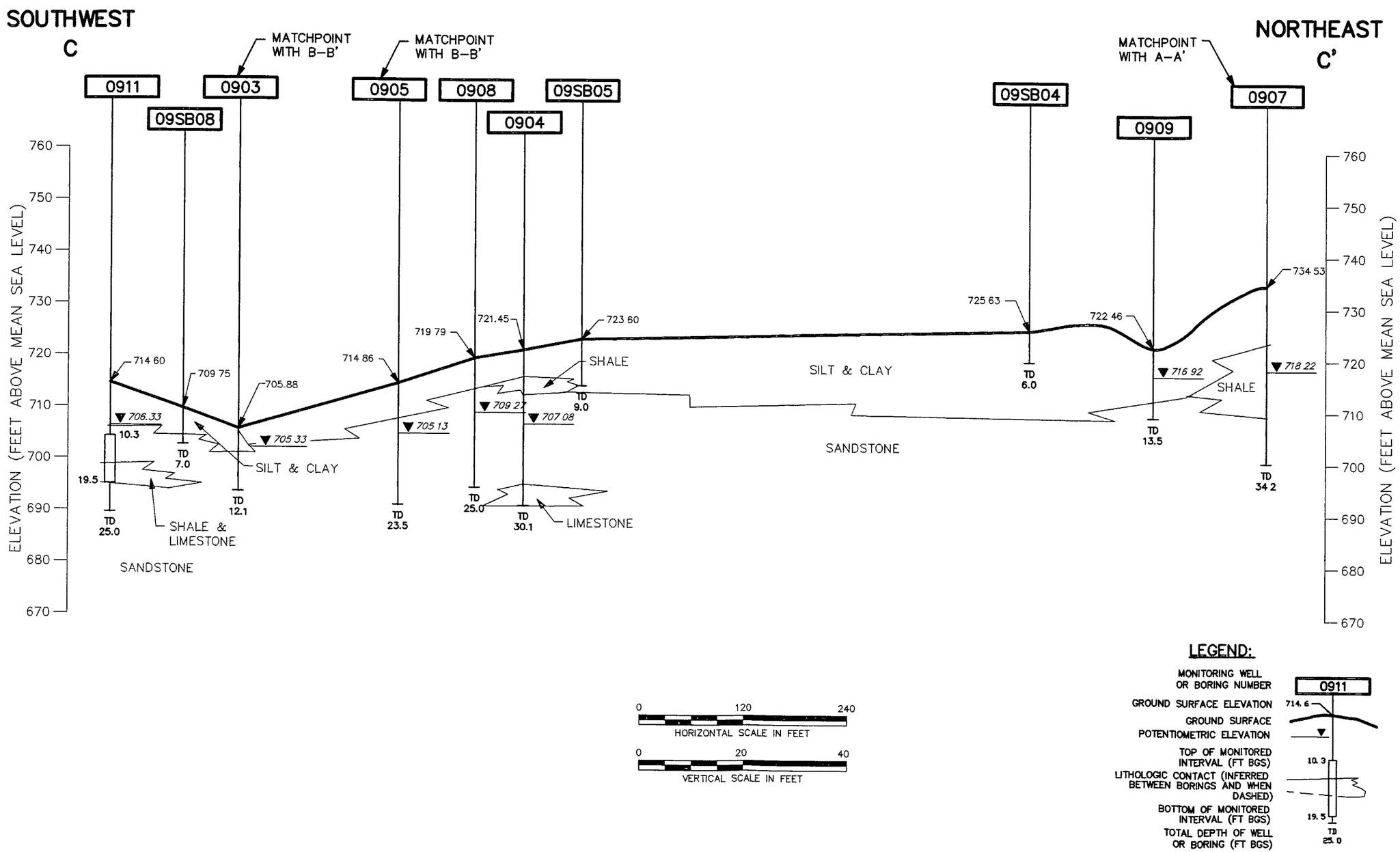
ACAD: 4267GX04.dwg 12/16/04 MF PIT

FORM CADD NO. SDIV-BV.DWG - REV 1 - 9/10/98



CONTRACT NO. 4267
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DATE
REV. 0
DRAWING NO. FIGURE 1-8

GEOLOGIC CROSS SECTION C-C'
CMS REPORT FOR
SWMU 9 - PESTICIDE CONTROL/
R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

NAVFAC

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FORM CADD NO. SDIV-BV.DWG - REV 1 - 9/10/98

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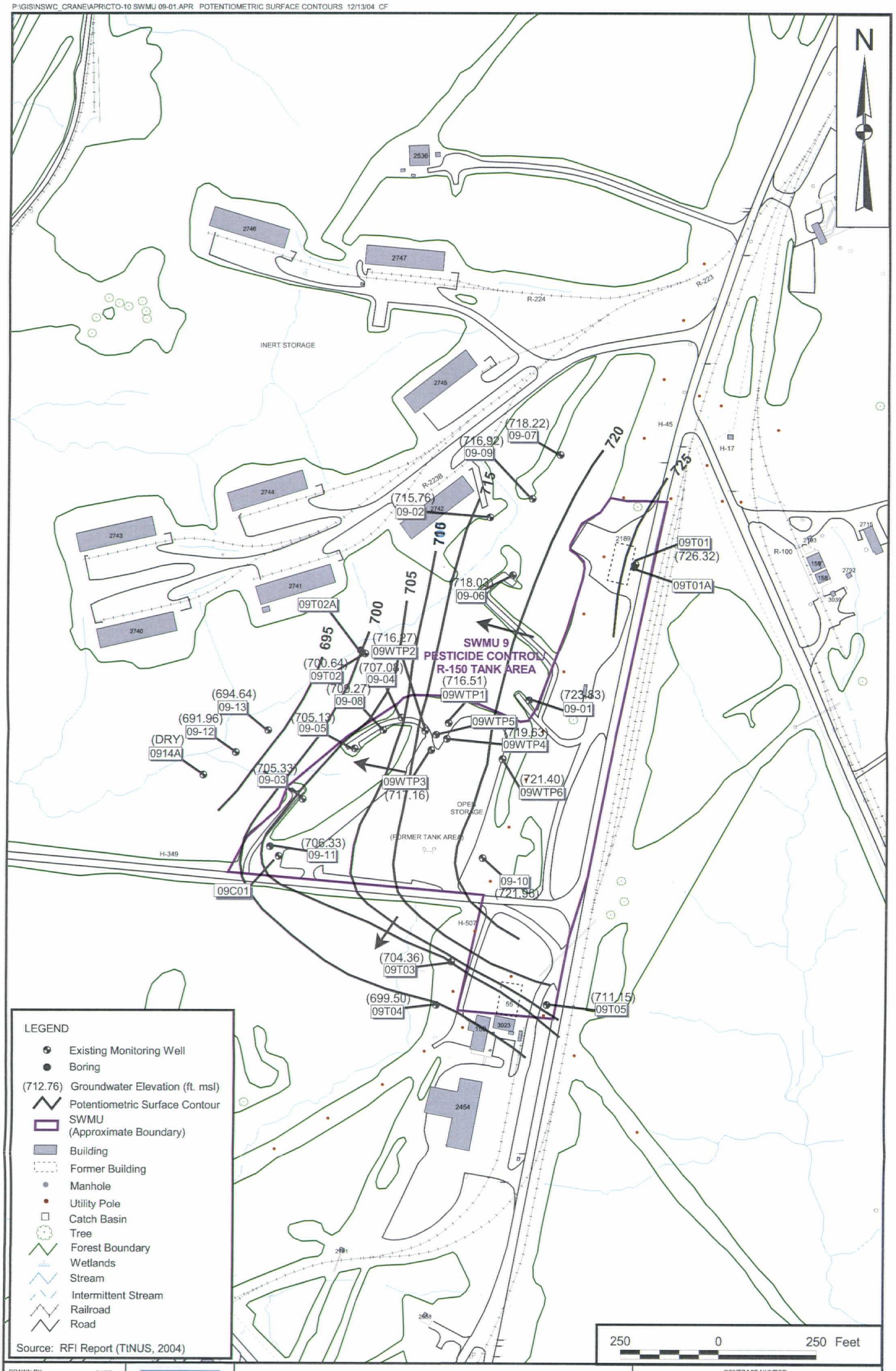

DRAWN BY K. PEILA	DATE 5/21/02	POTENTIOMETRIC SURFACE MAP (1-10-01) CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N4267
CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		DRAWING NO. FIGURE 1 - 9 REV 0

2.0 DESCRIPTION OF CURRENT CONDITIONS

This section presents a summary of the current contamination conditions for SWMU 9. The discussion is extracted from a more complete presentation in the RFI Report. The following discussions are presented in summary:

- Nature and extent of contamination
- Human health and ecological risk assessment drivers.
- Contamination fate and transport.

2.1 NATURE AND EXTENT OF CONTAMINATION

This section provides a general overview of the RFI investigation and results which were used as the basis for determining which media required consideration in the CMS for one or more contaminants. Tables 2-1 through 2-5 summarize by media (surface soil, subsurface soil, groundwater, surface water, and sediment) the chemicals detected, chemicals of potential concern (COPCs), and risk drivers. Following is a discussion of the information presented in Tables 2-1 through 2-5. Additional information can be found in the December 2004 RFI Report for SWMUs 4, 5, 9, and 10 (TtNUS, 2004).

2.1.1 Surface Soil

Eleven surface soil samples were collected. All eleven surface soil samples were analyzed for Appendix IX VOCs, Appendix IX semi-VOCs (SVOCs), Appendix IX pesticides, Appendix IX polychlorinated biphenyls (PCBs), Appendix IX herbicides, Target Analyte List (TAL) metals (plus tin), and cyanide. Additionally, three surface soil samples were analyzed for cation exchange capacity (CEC), pH, and total organic carbon (TOC). Table 2-1 summarizes the chemicals detected, COPCs, and human health and ecological risk drivers for surface soil.

VOCs: Methylene chloride was detected in five of the eleven surface soil samples analyzed. Methylene chloride concentrations ranged from 4 to 6 micrograms per kilogram (µg/kg). This compound was detected in samples 09SB010102 and 09SB030102 in the vicinity of former Building 2189, in sample 09SB080102 in the vicinity of former R-150 Tank Area, and in samples 09SB090102 and 09SB100102 in the vicinity of former Building 55. Methylene chloride is not likely to be site-related (TtNUS, 2004).

Figure 2-1 shows the locations where VOCs were detected and concentrations in surface soil at SWMU 9.

SVOCs: Seventeen polynuclear aromatic hydrocarbons (PAHs) and di-n-butyl phthalate were detected in surface soil samples; no other semivolatiles were detected. Di-n-butyl phthalate was detected in sample 09SB020002 at a concentration of 1,200 µg/kg. Maximum detected concentrations of the PAHs ranged from 18 µg/kg (acenaphthylene) to 1,800 µg/kg (2-methylnaphthalene). PAHs were detected in 5 of the 11 samples collected. All 17 PAHs were detected in sample 09SB030002, which is located in the vicinity of former Building 55 in the eastern portion of SWMU 9; the maximum detected concentrations of 14 of these 17 PAHs were found in this sample. Sample 09SB030002 was collected just south of former Building 2189, which is also located in the eastern portion of SWMU 9. Maximum concentrations of the remaining three PAHs (2-methylnaphthalene, naphthalene, and phenanthrene) were found in sample 09SB090002, which is located in the southeastern portion of SWMU 9. Benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, and pyrene were the most frequently detected PAHs (detected in 5 of 11 samples).

In general, there was no distinguishable pattern of PAH contamination. The PAHs may be attributable to asphalt, road traffic, or waste oil. The presence of di-n-butyl phthalate in sample 09SB020002 (located on the western side of Building 2189) may be resultant of site activities because di-n-butyl phthalate is used in pesticide formulation. Pesticide spray tanks and containers were reportedly rinsed on the western side of Building 2189.

Figure 2-1 shows the locations where SVOCs were detected and concentrations in surface soil at SWMU 9.

Pesticides/PCBs: 4,4'-DDT and methoxychlor were the only pesticides detected in the surface soil samples at concentrations of 4.7 and 25 µg/kg, respectively. This sample is located in the southern portion of the site near the location of Former Building 55. It is likely that the presence of these pesticides is attributable to past site activities such as spraying and possibly release through disposal.

No PCBs were detected at SWMU 9 in surface soils.

Figure 2-1 shows the locations where pesticides were detected and concentrations in surface soil at SWMU 9.

Herbicides: The herbicides 2,4-D, dinoseb, and pentachlorophenol were detected at SWMU 9. 2,4-D was detected in sample 09SB040002 (20 µg/kg). Dinoseb was detected in sample 09SB080002 at a concentration of 14 µg/kg. Pentachlorophenol was detected in samples 09SB020002 (3.5 µg/kg),

09SB040002 (2.0 µg/kg), and 05SB070002 (1.2 µg/kg). Samples 09SB020002 and 09SB040002 were collected west of former Building 2189. Sample 09SB080002 was located west of the former R-150 Tank, and sample 09SB070002 was collected north of the former R-150 Tank. It is likely that the presence of these pesticides is attributable to past site activities such as spraying and possibly release through disposal.

Figure 2-1 shows the locations where the herbicides were detected and concentrations in surface soil at SWMU 9.

Metals: Eighteen metals (aluminum, antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, vanadium, and zinc) were detected in the surface soil samples. Nine of the 18 detected metals (aluminum, arsenic, barium, chromium, cobalt, iron, manganese, nickel, and vanadium) were detected in all 11 samples at concentrations statistically determined to be similar to background concentrations. Cadmium was detected in 1 and mercury was detected in 5 of the 11 samples at concentrations statistically determined to be similar to background concentrations. Additionally, three of the detected metals (calcium, magnesium, and potassium) are considered to be essential nutrients.

Antimony, copper, lead, and zinc concentrations were statistically determined to exceed the background concentrations. Antimony was detected in 2 of the 11 samples at concentrations ranging from 0.97 to 3.1 milligrams per kilogram (mg/kg) with the maximum concentration in sample 09SB060002, which is located just north of the former R-150 Tank. Copper was detected in all 11 samples at concentrations ranging from 7.6 to 20.1 mg/kg with the maximum concentration in sample 09SB100002, which located in the vicinity of former Building 55. Lead was also detected in all 11 samples at concentrations ranging from 8.6 to 34.9 mg/kg with the maximum concentration in sample 09SB100002. Zinc was detected in all 11 samples at concentrations ranging from 30.3 to 120 mg/kg with the maximum concentration in sample 09SB060002.

Although metals were found frequently throughout SWMU 9, there was no apparent pattern to the metal detections. It is unlikely that these metals concentrations are related to site activities, as evidenced by the few metals detected above background concentrations and the low concentrations of these metals.

Figure 2-2 shows the locations where the metals were detected and concentrations in surface soil at SWMU 9.

Miscellaneous: Cyanide was not detected in SWMU 9 surface soil. Only samples 09SB040002, 09SB050002, and 09SB070002 were analyzed for miscellaneous parameters. TOC concentrations ranged from 5,700 to 8,500 mg/kg. CEC concentrations ranged from 8.4 to 11 milliequivalent per 100 grams (meq/100 g). The pH ranged from 6.9 to 8.0, which is in the neutral range.

2.1.1.1 Contaminants Associated with Human Health Risk

No significant potential health risks for human receptors were determined under current land use and future use for surface soils (TtNUS, 2004); therefore, surface soil will not be carried forward in the CMS.

2.1.1.2 Contaminants Associated with Ecological Risk

Several metals in the surface soil were detected at concentrations that exceed U.S. EPA Region 5 screening levels; however, few of the alternate guidelines or toxicity data are exceeded. Risks to wildlife from chemicals in the surface soil are expected to be low to negligible after taking home range and the uncertainties with bioaccumulation factors (BAFs) and Toxicity Reference Values (TRVs) into account. Therefore, risks to plants, invertebrates, mammals, and birds from chemicals in surface soil are expected to be low (TtNUS, 2004) and surface soil will not be carried forward in the CMS.

2.1.2 Subsurface Soil

Eleven subsurface soil samples were collected to evaluate the nature and extent of contamination. All 11 subsurface soil samples were analyzed for Appendix IX VOCs, Appendix IX SVOCs, Appendix IX pesticides, Appendix IX PCBs, Appendix IX herbicides, TAL metals (plus tin), and cyanide. Additionally, five subsurface soil samples were analyzed for CEC, pH, and TOC.

VOCs: Three VOCs [methylene chloride, tetrachloroethene (PCE), and trichloroethene (TCE)] were detected in one to six of the 11 subsurface soil samples. The detected VOCs are common solvents. Methylene chloride was detected in six of the 11 subsurface soil samples analyzed. Methylene chloride concentrations ranged from 3 to 6 µg/kg. These concentrations of methylene chloride are similar to those found in laboratory blanks. Additionally, methylene chloride was detected at similar concentrations in surface soil samples and in some of the same sample locations. The available evidence suggests that the methylene chloride concentrations are a laboratory contamination artifact rather than an indication of a methylene chloride release at SMWU 9. PCE and TCE were detected at concentrations of 4 and 18 µg/kg, respectively, in sample 09SB070709, which is located in the vicinity of former R-150 Tank. R-150 Tank is known to have contained chlorinated hydrocarbons. Tetrachloroethene and

trichloroethene were not detected in surface soil. These two chemicals are likely to be related to site activities.

Figure 2-3 shows the locations where the VOCs were detected and concentration in subsurface soil at SWMU 9.

SVOCs: Bis(2-ethylhexyl) phthalate was the only SVOC detected in the subsurface soil samples. Bis(2-ethylhexyl) phthalate was detected in sample 09SB070709 (660 µg/kg). There is no known source of this compound at SWMU 9; however, bis(2-ethylhexyl) phthalate is a common component of plastics which are commonly detected in environmental media.

Figure 2-3 shows the locations where the SVOCs were detected and concentration in subsurface soil at SWMU 9.

Pesticides/PCBs: No pesticide compounds were detected in subsurface soil samples.

Aroclor 1254 was detected at a concentration of 460 µg/kg in sample 09SB070709, which is located in the vicinity of the former R-150 Tank. PCBs were not detected in any of the surface soil samples. As previously stated, R-150 Tank is known to have contained chlorinated hydrocarbons. The presence of Aroclor 1254 is probably related to past disposal activities at this site because the observed concentration is relatively high (i.e., greater than 250 µg/kg). This level of detection in a single sample may indicate an isolated contamination hotspot. However, the PCB concentration (460 µg/kg) is below the Toxic Substance Control Act (TSCA) remediation level of 1,000 µg/kg contained in TSCA regulations [40 CFR Part 761.61(a)(4)(i)(A)] for high occupancy areas.

Figure 2-3 shows the locations where the herbicide was detected and concentration in subsurface soil at SWMU 9.

Herbicides: Pentachlorophenol was detected in sample 09SB0110406 at a concentration of 1.4 µg/kg. Pentachlorophenol was detected more frequently in surface soil samples but at approximately the same concentration. However, pentachlorophenol was not detected in the surface soil sample collected from location 09SB11.

Figure 2-3 shows herbicides location and concentrations in subsurface soil at SWMU 9.

Metals: Eighteen metals (aluminum, antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, vanadium, and zinc) were detected in the subsurface soil samples. Cadmium, selenium, silver, sodium, thallium, and tin were not detected in any of these subsurface soil samples. Of the 18 detected metals, arsenic and vanadium were detected in all 11 samples at concentrations statistically determined to be similar to background concentrations. Antimony and mercury were detected at low frequencies (in two of the 11 samples), but at concentrations statistically determined to be similar to background concentrations. Additionally, three of the detected metals (calcium, magnesium, and potassium) are considered to be essential nutrients and will not be discussed any further.

Aluminum, arsenic, barium, chromium, copper, iron, lead, nickel, vanadium, and zinc concentrations were statistically determined to exceed background concentrations for Soil Group 9. These metals were detected in all of the 11 samples. The maximum detected concentrations of these metals were divided among several sample locations, but the concentrations are generally comparable to Soil Group 8 concentrations.

Although frequently detected, there was no pattern to the metals found. The same metals that were detected in the surface soil were also detected in the subsurface soil samples; however, concentrations of the majority of these metals exceed background concentrations in subsurface soil.

Figure 2-4 shows the locations where the metals were detected and concentration in subsurface soil at SWMU 9.

Miscellaneous Parameters: Cyanide was not detected in subsurface soil samples.

Only samples 09SB010810, 09SB030406, 09SB080406, 09SB090810, and 09SB100204 were analyzed for miscellaneous parameters. TOC ranged from 1,200 to 6,500 mg/kg. CEC ranged from 7.4 to 13 meq/100 g. The pH ranged from 4.3 to 6.9 (slightly acidic to neutral).

2.1.2.1 Contaminants Associated with Human Health Risk

No significant potential health risks for human receptors were determined under current land use and future use for subsurface soils (TtNUS, 2004); therefore, subsurface soil will not be carried forward in the CMS.

2.1.3 Groundwater

Twelve groundwater samples and one upgradient groundwater sample (09GWTP0601) were collected to evaluate the nature and extent of contamination. All groundwater samples were analyzed for Appendix IX VOCs, Appendix IX SVOCs, Appendix IX pesticides, Appendix IX PCBs, Appendix IX herbicides, total TAL metals (plus tin), and cyanide. None of the samples were analyzed for dissolved TAL metals.

VOCs: 1,1,1-trichloroethane (TCA), 1,1-dichloroethane (DCA), 1,1-dichloroethene (DCE), cis-1,2-DCE, methylene chloride, and TCE were detected in SWMU 9 groundwater samples. 1,1,1-TCA, 1,1-DCA, and 1,1-DCE were detected in sample 09GW0301 at concentrations of 26, 14, and 6.4 microgram per liter (µg/L), respectively. Cis-1,2-DCE was detected in 09GW0301 (69 µg/L), 09GW0401 (130 µg/L), and 09GWT0201 (1.7 µg/L). Methylene chloride was detected in sample 09GW0401 at a concentration of 58 µg/L. TCE was detected in samples 09GW0301 (55 µg/L) and 09GW01001 (1 µg/L).

Well 09-03, which is located southwest of the former tank, contained five of the six detected VOCs. Well 09-10, which is southeast of the historic locations, contained TCE at 1 µg/L. Well 09-04, which is west of wells 09WTP-1 through 09WTP-4, contained cis-1,2-DCE at 130 µg/L and methylene chloride at 58 µg/L. Well 09T02, which is northwest of the historic wells, contained cis-1,2-DCE at 1.7 µg/L. Monitoring wells located farther north (northwest and northeast) and farther south (southwest and southeast) did not contain VOCs.

Some of these VOCs were also detected in SWMU 9 subsurface soil sample 09SB070102, which is located just south of historic well location 09-WTP03. The presence of these VOCs in groundwater is likely a result of leakage from the former R-150 Tank.

Figure 2-5 shows the locations where VOCs were detected and concentrations in groundwater at SWMU 9. Ingestion of groundwater containing cis-1,2-DCE is a risk driver for the future child resident.

SVOCs: No SVOCs were detected in SWMU 9 groundwater.

Pesticides/PCBs: Dieldrin was detected at a concentration of 0.03 µg/L in sample 09GWT0101, which is located on the eastern side of former Building 2189. No other pesticides were detected in SWMU 9 groundwater samples. Dieldrin was not detected in surface or subsurface soil at SWMU 9.

No PCBs were detected in SWMU 9 groundwater.

Figure 2-5 shows the location where the pesticide was detected and concentration in groundwater at SWMU 9.

Herbicides: 2,4,5-T was detected at a concentration of 0.13 µg/L in sample 09GWT0101, which is collected along the eastern side of former Building 2189, and 2,4,5-TP (Silvex) was detected at a concentration of 0.17 µg/L in sample 09GW1201, which is located west of the former R-150 Tank Area (the westernmost sample location at SWMU 9). These herbicides were not detected in surface or subsurface soil samples collected at SWMU 9.

Figure 2-5 shows the locations where the herbicides were detected and concentrations in groundwater at SWMU 9.

Metals: Sixteen metals (aluminum, arsenic, barium, beryllium, calcium, cobalt, copper, iron, lead, magnesium, manganese, nickel, selenium, sodium, vanadium, and zinc) were detected in groundwater samples. The maximum detected concentrations of these 16 metals were in excess of respective upgradient concentrations. Antimony, cadmium, chromium, silver, thallium, mercury, potassium, and tin were not detected in these groundwater samples. Three of the detected metals (calcium, magnesium, and sodium) are considered to be essential nutrients and will not be discussed any further.

Arsenic, barium, and manganese were detected in all 12 groundwater samples at maximum concentrations of 4.3, 323, and 7,920 µg/L, respectively; these all occurred in sample 09GW0201. Aluminum and beryllium were both detected in 2 of the 12 samples. The maximum detected concentrations of aluminum (1,290 µg/L) and beryllium (4.4 µg/L) were found in sample 09GWT0201. Lead was detected in sample 09GW0401 at a concentration of 1.1 µg/L. Vanadium was detected in sample 09GWT0101 at a concentration of 2.1 µg/L. Zinc and nickel were both detected in 6 of the 12 samples. The maximum detected concentrations of zinc (166 µg/L) and nickel (279 µg/L) were found in sample 09GWT0201. Copper was detected in 4 of the 12 samples at concentrations ranging from 2 to 8.4 µg/L; the maximum detection occurred in sample 09GWT0201. Cobalt was detected in 7 of the 12 samples at concentrations ranging from 11.6 to 109 µg/L; the maximum occurred in sample 0909GWT0201. Iron was detected in 11 of the 12 samples at concentrations ranging from 136 to 37,300 µg/L; the maximum was in sample 09GW0201. Selenium was detected in 3 of the 12 samples at concentrations ranging from 1.2 to 1.7 µg/L. The maximum detected concentration of selenium occurred in sample 09GWT0201.

Barium, iron, manganese, selenium, and zinc were detected in the upgradient sample (09GWTP0601). The concentrations of these metals in sample 09GWTP0601 were less than those detected in downgradient samples.

The maximum detected concentrations were divided among five of the 12 sample locations with no decernable pattern of metals contamination in the groundwater. These metals were also detected in surface and subsurface soil samples at SWMU 9. The highest iron and manganese concentrations typically was observed with the elevated VOC concentrations. The other metals do not coincide with significant VOC, pesticide, or herbicide detections. Maximum detections occurred most frequently in samples 09GW0201, which is located west of former Building 2189, and 09GWT0201, which is located northwest of the former R-150 Tank.

Figure 2-5 shows the locations where the metals were detected and concentration in groundwater at SWMU 9. Ingestion of iron and manganese is a risk driver for the future adult and child resident. Additionally, ingestion of groundwater containing nickel and dermal contact with groundwater containing manganese are risk drivers for the future child resident.

Miscellaneous Parameters: Cyanide was not detected in these groundwater samples.

2.1.3.1 Contaminants Associated with Human Health Risk

No significant potential health risks for human receptors were determined under current land use. Under future land use, elevated noncarcinogenic and carcinogenic risks were calculated for potential residential exposure to chlorinated VOCs (cis-1,2-DCE, 1,1-DCE, TCE), arsenic, iron, manganese, and nickel in groundwater.

However, significant uncertainties are associated with the risks calculated for these risk drivers: uncertainty in the assumption of residential exposure, uncertainty in the exposure point concentrations because of the use of maximum concentrations to estimate potential risks, uncertainty in the toxicity of 1,1-DCE, arsenic, and iron, and uncertainty in the selection of arsenic as a COPC because the concentrations of arsenic are probably within naturally occurring background levels at the site (TtNUS, 2004).

The risks calculated for cis-1,2-DCE were based on the maximum detected concentration [0.13 milligrams per liter (mg/L)] of this compound because the 95 percent Upper Confidence Limit (UCL) exceeded the maximum. Cis-1,2-DCE was detected in 3 of the 12 groundwater samples, with an average concentration

of 0.02 mg/L. It is likely that the risks from cis-1,2-DCE in groundwater are overestimated by assuming that hypothetical future residents are exposed to the maximum concentration for a lifetime.

The residential groundwater scenario assumes that groundwater at the site is used as a source of domestic drinking water. However, because of the shallow depth to groundwater and the nature of the site, it is unlikely that groundwater at the site would be used as a source of potable water in the future

2.1.3.2 Contaminants Associated with Ecological Risk

There is no unacceptable ecological risk associated with groundwater.

2.1.4 Surface Water

Four surface water samples and one upgradient surface water sample (09SW0101) were collected to evaluate the nature and extent of contamination. The surface water samples were analyzed for Appendix IX VOCs, Appendix IX SVOCs, Appendix IX pesticides, Appendix IX PCBs, Appendix IX herbicides, total and dissolved TAL metals (plus tin), cyanide, hardness, and total suspended solids. The upgradient sample was 09SW0101.

VOCs: No VOCs were detected in SWMU 9 surface water samples.

SVOCs: No SVOCs were detected in SWMU 9 surface water samples.

Pesticides/PCBs: No pesticide/PCBs were detected in SWMU 9 surface water samples.

Herbicides: 2,4-D was detected in sample 09SW0201 at a concentration of 0.18 µg/L, which is just two times the detection limit. This sample is located about 400 feet west of former Building 2189 and the concentration does not exceed any risk based criteria.

Figure 2-6 shows the location where the herbicide was detected and concentration in surface water at SWMU 9.

Metals: Fifteen metals (aluminum, antimony, arsenic, barium, calcium, cobalt, copper, iron, lead, magnesium, manganese, potassium, sodium, vanadium, and zinc) were detected in these surface water samples. Four of the detected metals (calcium, magnesium, potassium, and sodium) are considered to be essential nutrients and will not be discussed any further.

Arsenic, barium, iron, and manganese were detected in all four surface water samples. The maximum detected concentrations of arsenic, barium, and iron were found in sample 09SW0501. The maximum detected concentration of manganese was found in sample 09SW0201. The remaining detected metals were present in from one to two of the four samples collected. Maximum detected concentrations of the majority of the metals detected in surface water were found in sample 09SW0501.

Antimony had a maximum detected concentration (1.6 µg/L) that was in excess of upgradient concentrations. This sample was collected in the southernmost location at SWMU 9 (southwest of former Building 55).

The surface water samples were also analyzed for dissolved metals. Except for aluminum, all the metals detected in the total (unfiltered samples) were detected in the dissolved (filtered) metals samples. The concentrations and frequencies of detection of these metals were similar to those found in the total (unfiltered) samples; however, the majority of the dissolved metals concentrations were in excess of upgradient concentrations. Dissolved concentrations of barium was the only metal not in excess of dissolved upgradient concentrations. The maximum detected concentrations of all metals except manganese were detected in sample 09SW0501, which, as noted above, was collected in the southernmost location at SWMU 9 (southwest of former Building 55).

There does not appear to be a pattern of metals contamination in the surface water. Additionally, the upgradient (background) sample 09SW0101 contained metals concentrations in excess of those found in the other surface water samples at SWMU 6. However, the dissolved (filtered) results for this sample were very similar to metals results for all other samples collected within SWMU 9. Furthermore, the total suspended solids (TSS) results for sample 09SW0101 were one order of magnitude greater than in the other samples, substantiating that the elevated metals in the unfiltered (total) sample were due to suspended solids. These metals were also detected in surface soil, subsurface soil, and groundwater samples at SWMU 9. These metals do not coincide with significant VOC, pesticide, or herbicide detections.

Figure 2-6 shows the locations where the metals were detected and concentration in surface water at SWMU 9.

Miscellaneous Parameters: Cyanide was not detected. The hardness of these samples ranged from 70 to 180 mg/L, and the total suspended solids ranged from 3 to 10 mg/L. Sample 09SW0501 possessed the maximum hardness value, and sample 09SW0401 possessed the maximum TSS value.

2.1.4.1 Contaminants Associated with Human Health Risk

No significant potential health risks for human receptors were determined under current or future land use associated with surface water.

2.1.4.2 Contaminants Associated with Ecological Risk

Risks to aquatic receptors from chemicals in the surface water are expected to be low or negligible based on their relatively low concentrations compared to the screening levels or alternate benchmarks. There may be some risks from iron and manganese in the surface water.

Risks to wildlife from chemicals in the surface water are expected to be low to negligible after taking home range and the uncertainties with BAFs and TRVs into account. There is no unacceptable ecological risk associated with surface water.

2.1.5 Sediment

Four sediment samples and one upgradient sediment sample (09SD010006) were collected to evaluate the nature and extent of contamination. All sediment samples were analyzed for Appendix IX VOCs, Appendix IX SVOCs, Appendix IX pesticides, Appendix IX PCBs, Appendix IX herbicides, TAL metals (plus tin), cyanide, and TOC.

VOCs: Methylene chloride was the only VOC detected in these sediment samples. Methylene chloride was detected at a concentration of 4 µg/kg in both samples 09SD030006 and 09SD040006. Methylene chloride was also detected at a concentration of 8 µg/kg in sample 04SD010006, which was collected upgradient of SWMU 9. This compound is considered a common laboratory contaminant, and the low concentrations (i.e., near the detection limit 4 µg/kg) found in these SWMU 9 sediments are similar to those concentrations commonly found in laboratory method blanks. Methylene chloride was also detected in surface and subsurface soil samples from SWMU 9 at concentrations that were also near the detection limit of 4 µg/kg.

Figure 2-7 shows the locations where VOCs were detected and concentration in sediment at SWMU 9.

SVOCs: Fluoranthene was the only SVOC detected in site-related sediment samples. Fluoranthene was detected at a concentration of 10 µg/kg in sample 09SD030006, which was collected west of the former R-150 Tank Area. This PAH was also detected in one surface soil sample in the vicinity of the former

R-150 Tank. However, PAHs were not detected in subsurface soil, groundwater, or surface water samples from this area.

The upgradient sediment location (09SD010006) for SWMU 9 contained benzo(b)fluoranthene (14 µg/kg), chrysene (11 µg/kg), and pyrene (14 µg/kg), indicating that these PAHs may not be site related but may be the resultant of roadway runoff as PAHs are components of vehicular exhaust and asphalt.

Figure 2-7 shows the locations where SVOCs were detected and concentration in sediment at SWMU 9.

Pesticides/PCBs: No pesticides were detected in SWMU 9 sediment samples.

Aroclor 1248 was detected at a concentration of 380 µg/kg in sample 09SD030006, which was collected west of the former R-150 Tank Area. The only other detection of PCBs in any media was in subsurface soil sample 09SB070709, which is in the vicinity of the former R-150 Tank where chlorinated hydrocarbons spills were know to have occurred. The presence of Aroclor 1248 is probably related to past disposal activities at this site because the observed concentration is relatively high (i.e., greater than 350 µg/kg). These sample locations are about 400 feet from each other and suggest that the area of contamination is associated with the former R-150 Tank.

Figure 2-7 shows the locations where the PCBs were detected and concentration in sediment at SWMU 9.

Herbicides: Herbicides were not detected in any sediment samples collected for SWMU 9. However, the upgradient sediment location for SWMU 9 contained dinoseb (8.2 µg/kg) and pentachlorophenol (2.7 µg/kg), indicating that these herbicides may not be site related but are resultant of basewide applications. This would be consistent with the infrequent detections of herbicides at SWMU 9.

Figure 2-7 shows the locations where the herbicides were detected and concentration in sediment at SWMU 9.

Metals: Sixteen metals (aluminum, antimony, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, vanadium, and zinc) were detected in these sediment samples. Of these 16 metals, the maximum detected concentrations of aluminum, antimony, arsenic, barium, copper, chromium, cobalt, iron, lead, magnesium, manganese, potassium, vanadium, and zinc were in excess of respective upgradient concentrations. Three of the detected metals (calcium, potassium, and magnesium) are considered to be essential nutrients and will not be discussed any

further. Of the metals detected above upgradient concentrations, antimony was the only metal that was detected in less than all four samples. Antimony was detected only in sample 09SD020006 at a concentration of 1.3 mg/kg.

The remaining metals were detected in all four samples. Maximum detected concentrations for aluminum, copper, and chromium were found in sample 09SD050006. Maximum detection concentrations of arsenic, barium, iron, lead, manganese, vanadium, and zinc were found in sample 09SD030006. The maximum detected concentration of cobalt was found in sample 09SD040006.

Aluminum concentrations ranged from 5,470 to 10,800 mg/kg. Chromium concentrations ranged from 11.1 to 13 mg/kg. Arsenic concentrations ranged from 0.77 to 6.1 mg/kg. Iron concentrations ranged from 15,700 to 18,600 mg/kg. Manganese concentrations ranged from 86.8 to 1,300 mg/kg. Vanadium detections ranged from 12.2 to 21.2 mg/kg. Zinc concentrations ranged from 27.7 to 95.3 mg/kg. Cobalt concentrations ranged from 4.8 to 14.5 mg/kg. Barium concentrations ranged from 39.3 to 103 mg/kg. Copper concentrations ranged from 9 to 27.7 mg/kg. Lead concentrations ranged from 6.6 to 27.7 mg/kg.

The concentrations of metals detected across SWMU 9 sediment are similar. The concentrations of metals detected in sediment samples collected within SWMU 9 (including the upgradient location 09SD010006) are generally within one order of magnitude of each other. These metals were also detected in surface soil, subsurface soil, groundwater, and surface water samples at SWMU 9.

Figure 2-7 shows the locations where the metals were detected and concentration in sediment at SWMU 9.

Miscellaneous Parameters: Cyanide was not detected in these sediment samples. The TOC ranged from 1,600 mg/kg (09SD050006) to 14,000 mg/kg (09SD040006) in these sediment samples.

2.1.5.1 Contaminants Associated with Human Health Risk

No significant potential health risks for human receptors were determined under current or future land use associated with sediment.

2.1.5.2 Contaminants Associated with Ecological Risk

Risks to aquatic receptors from chemicals in the sediment are expected to be low or negligible based on their relatively low concentrations compared to the screening levels or alternate benchmarks. Risks to

wildlife from chemicals in the sediment are expected to be low to negligible after taking home range and the uncertainties with BAFs and TRVs into account. There is no unacceptable ecological risk associated with sediment.

2.2 CONTAMINANT FATE AND TRANSPORT

This section presents a brief overview of contaminant fate and transport issues at SWMU 9. This discussion focuses on some of the major types of contaminants found at the site.

Based on a review of the existing data for the site, a release of hazardous constituents to the surrounding soil has occurred as a result of historical site operations (i.e., pesticide management operations and waste solvents storage). The historical data also indicate that residual contaminants in the soil have migrated to groundwater via infiltration and percolation. Additional release mechanisms, which are also expected to contribute to the contaminant transport, include discharge of groundwater to surface water and sediment (unnamed tributaries), deposition via surface water runoff, and generation of fugitive dust and volatile emissions from soil.

The following classes of chemicals were detected in the media of concern at SWMU 9.

Soil - VOCs, PAHs, pesticides, PCBs, herbicides, and metals
Groundwater - VOCs, pesticides, herbicides, and metals
Surface Water - Herbicides (2,4-D) and metals
Sediment - PAHs (Fluoranthene), PCBs, herbicides (pentachlorophenol), and metals

Fate and transport characteristics of these chemicals are briefly discussed in the following sections.

<u>VOCs:</u> VOCs are typically considered to be fairly soluble and to have a low capacity for retention by soil organic carbon; therefore, these compounds are most frequently detected in groundwater. These types of chemicals may migrate through the soil column after they are released by a spill event or by subsurface waste burial as infiltrating precipitation solubilizes them. Some portion of these chemicals is retained by the soil, but most will continue migrating downward until they reach the water table. At that time, migration is primarily lateral with the hydraulic gradient. They may have migrated to surface water and sediment, but attenuation and dilution factors, such as volatilization, have resulted in their disappearance.

Three chlorinated VOCs were detected infrequently in soil samples at SWMU 9 (in one of 22 surface/subsurface soil samples) and seven chlorinated VOCs were detected in 3 of the 12 groundwater samples. The VOCs in groundwater include the degradation products of PCE and TCE and are indicative of the natural attenuation of this class of chemicals. The soil and groundwater data indicate that some impact of VOCs in soil on groundwater may have occurred at the site.

SVOCs: SVOCs are generally considered to be fairly immobile chemicals in the environment. They are large molecules with high organic carbon partition coefficients and low solubilities when compared to the volatile organics. These compounds, when found in the soil, generally do not migrate vertically to a great extent. Instead, they are more likely to adhere to soil particles and be removed from the site via surface runoff and erosional processes. Their absence in groundwater is evidence of their immobility. Their presence in sediment may stem from surface erosion, but their absence in surface water is consistent with their low water solubilities and their ability to bind to soil and sediment.

Pesticides/PCBs: Pesticides were widely used at NSWC Crane. Many of the detected compounds are no longer licensed for general sale and use in the United States. Therefore, it is assumed that much of what was detected at SWMU 9 is representative of past application for insect control.

Like SVOCs, pesticides as a class of compounds are not considered to be very mobile in the environment. These chemicals, upon application or disposal, tend to remain affixed to soil particles. Migration of pesticides occurs primarily by erosion via the action of wind or water. Erosion accounts for their presence in sediment. Their absence in groundwater and surface water is consistent with their ability to bind to soil and sediment and their low solubility in water.

PCBs are considered to be very persistent organic chemicals. Biodegradation is the only process known to transform PCBs under environmental conditions, and only the lighter compounds are measurably biodegraded. As with PAHs and pesticides, their absence in groundwater and surface water is consistent with their ability to bind to soil and sediment and of their low solubility in water.

Herbicides: Herbicides were widely used at NSWC Crane. Many of the detected compounds are no longer licensed for general sale and use in the United States. Therefore, it is assumed that much of what was detected at SWMU 9 is representative of past application for foliage control.

The persistence and mobility of herbicides in soil depend greatly on soil type, moisture, temperature, and microbial community.

Metals: Because inorganics are frequently incorporated into the soil matrix and remain bound to particulate matter, they also migrate from the source areas via bulk movement processes (erosion). The larger particles (greater than 0.45 microns, which are removed via the filtration step prior to water analysis) are not generally considered to be mobile in groundwater. The metals detected in unfiltered groundwater samples are likely to be representative of suspended soil material in the samples.

There are some instances, however, where these metals are found at such concentrations or in such form as to be able to migrate in solution. It is possible that industrial activities could saturate all available exchange sites in soil and result in a metal being mobilized. Metals are also more mobile under acidic conditions, which may exist in areas where plating-type activities have occurred. Finally, a metal solution may be utilized in some industrial applications. In these cases, it is possible for metals to migrate vertically through the soil column and reach the groundwater.

2.3 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

2.3.1 Human Health Risk Assessment

A baseline human health risk assessment for SWMU 9 was performed to characterize the potential risks to likely human receptors under current and potential future land use. Potential receptors under current land use are construction workers, maintenance workers, and adolescent trespassers. Potential receptors under future land use are recreational users and hypothetical residents (children and adults). Although future land use is likely to be the same as current land use, potential future receptors were evaluated in the baseline human health risk assessment, primarily for decision-making purposes. A LUC program is not currently in place at NSWC Crane.

Quantitative estimates of non-carcinogenic and carcinogenic risks [Hazard Indices (HIs) and Incremental Lifetime Cancer Risks (ILCRs)] were developed for potential human receptors. Cumulative HIs for the construction worker, maintenance worker, occupational worker, adult recreational user, and adolescent trespasser under the Reasonable Maximum Exposure (RME) scenario are less than unity (1), indicating that adverse non-carcinogenic effects are not anticipated for these receptors under the defined exposure conditions. Cumulative HIs for the future adult and child resident exceed unity.

Cumulative HIs for the future adult and child residents are 14 and 47, respectively. These risks result from exposure to the maximum concentration of cis-1,2-DCE (adult HI = 0.49, child HI = 1.8), iron (adult HI = 1.7, child HI = 6.0), manganese (adult HI = 10, child HI = 35), and nickel (adult HI = 0.36, child HI = 1.3) in groundwater, primarily by ingestion. Table 2-6 provides a summary of hazard quotients (HQs)

for SWMU 9 as presented in the RFI. The HIs associated with direct exposure to other media at the site are minimal for all receptors (i.e., HIs are less than unity).

Cumulative ILCRs for the construction worker, maintenance worker, occupational worker, and adolescent trespasser are less than the U.S. EPA target risk range, $1x10^{-6}$ to $1x10^{-4}$. The ILCR for the future adult recreational user is within the U.S. EPA's target risk range. The total residential ILCR (adult + child) is 1.9×10^{-4}, which slightly exceeds the target risk range.

The elevated carcinogenic risks for residents are primarily a result of exposure to arsenic in groundwater (by ingestion) and sediment and to chlorinated volatile organics in groundwater. Arsenic accounts for approximately 48 percent of the total carcinogenic risk, and volatiles (namely, 1,1-DCE and TCE) account for 46 percent of the cancer risk.

2.3.2 Ecological Risk Assessment

A screening ecological risk assessment (SERA) was performed for the SWMU 9. The overall risks to terrestrial plants and soil invertebrates associated with the COPCs (di-n-butyl phthalate, naphthalene, methoxychlor, antimony, copper, lead, and zinc) in the soil are expected to be negligible. Risks to aquatic receptors in sediment at SWMU 9 are considered negligible for aluminum, antimony, Aroclor 1248, arsenic, barium, copper, iron, manganese, and vanadium. For surface water, the risks associated with copper lead and manganese are low while the risks associated with 2,4-D and cobalt are negligible. Higher risks associated with iron and manganese in some sample locations are possible. Based on the low Ecological Effects Quotient (EEQ) for Aroclor 1248 (EEQ = 2.8) and the large home range of the raccoon relative to the size of the water bodies at the SWMU, actual food chain modeling risks to the raccoon from PCBs are expected to be low and no fish were present (TtNUS, 2004).

TABLE 2-1

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SURFACE SOIL
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health		Ecological	
	COPCs	Risk Drivers	COPCs	Risk Drivers
Volatiles				
METHYLENE CHLORIDE	METHYLENE CHLORIDE			
Semi-Volatiles				
2-METHYLNAPHTHALENE	2-METHYLNAPHTHALENE			
ACENAPHTHENE				
ACENAPHTHYLENE				
ANTHRACENE				
BENZO(A)ANTHRACENE	BENZO(A)ANTHRACENE			
BENZO(A)PYRENE	BENZO(A)PYRENE			
BENZO(B)FLUORANTHENE	BENZO(B)FLUORANTHENE			
BENZO(G,H,I)PERYLENE				
BENZO(K)FLUORANTHENE				
CHRYSENE				
DI-N-BUTYL PHTHALATE			DI-N-BUTYL PHTHALATE	
DIBENZO(A,H)ANTHRACENE				
FLUORANTHENE				
FLUORENE				
INDENO(1,2,3-CD)PYRENE				
NAPHTHALENE	NAPHTHALENE		NAPHTHALENE	
PHENANTHRENE				
PYRENE				
Pesticides				
4,4'-DDT				
AROCLOR-1254				
METHOXYCHLOR			METHOXYCHLOR	
Herbicides				
2,4-D				
DINOSEB				
PENTACHLOROPHENOL	PENTACHLOROPHENOL			

TABLE 2-1

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SURFACE SOIL
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health		Ecological	
	COPCs	Risk Drivers	COPCs	Risk Drivers
Metals				
ALUMINUM				
ANTIMONY	ANTIMONY		ANTIMONY	
ARSENIC				
BARIUM				
CADMIUM				
CALCIUM				
CHROMIUM				
COBALT				
COPPER			COPPER	
IRON				
LEAD			LEAD	
MAGNESIUM				
MANGANESE				
MERCURY				
NICKEL				
POTASSIUM				
VANADIUM				
ZINC			ZINC	

COPCs — Chemicals of potential concern.

TABLE 2-2

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SUBSURFACE SOIL
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health	
	COPCs	Risk Drivers
Volatile Organics		
METHYLENE CHLORIDE	METHYLENE CHLORIDE	
TETRACHLOROETHENE	TETRACHLOROETHENE	
TRICHLOROETHENE	TRICHLOROETHENE	
Semi-Volatile Organics		
BIS(2-ETHYLHEXYL)PHTHALATE		
Pesticides/PCB's		
AROCLOR-1254	AROCLOR-1254	
Herbicides		
PENTACHLOROPHENOL	PENTACHLOROPHENOL	
Metals		
ALUMINUM	ALUMINUM	
ANTIMONY	ANTIMONY	
ARSENIC		
BARIUM	BARIUM	
BERYLLIUM	BERYLLIUM	
CALCIUM		
CHROMIUM	CHROMIUM	
COBALT		
COPPER		
IRON	IRON	
LEAD		
MAGNESIUM		
MANGANESE	MANGANESE	
MERCURY		
NICKEL	NICKEL	
POTASSIUM		
VANADIUM		
ZINC		

COPCs — Chemicals of potential concern.

TABLE 2-3

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR GROUNDWATER
SWMU 9 - PESTICIDE CONTROL/R-150
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health		
	COPCs	COCs	Risk Drivers
Volatile Organics			
1,1,1-TRICHLOROETHANE			
1,1-DICHLOROETHANE	1,1-DICHLOROETHANE	1,1-DICHLOROETHANE	
1,1-DICHLOROETHENE			
CIS-1,2-DICHLOROETHENE	CIS-1,2-DICHLOROETHENE	CIS-1,2-DICHLOROETHENE	CIS-1,2-DICHLOROETHENE
METHYLENE CHLORIDE	METHYLENE CHLORIDE		
TRICHLOROETHENE	TRICHLOROETHENE	TRICHLOROETHENE	
Pesticides/PCBs			
DIELDRIN	DIELDRIN	DIELDRIN	
Herbicides			
2,4,5-T			
2,4,5-TP (SILVEX)			
Metals			
ALUMINUM	ALUMINUM		
ARSENIC	ARSENIC	ARSENIC	
BARIUM	BARIUM		
BERYLLIUM	BERYLLIUM		
CALCIUM			
COBALT			
COPPER			
IRON	IRON	IRON	IRON
LEAD			
MAGNESIUM			
MANGANESE	MANGANESE	MANGANESE	MANGANESE
NICKEL	NICKEL	NICKEL	NICKEL
SELENIUM			
SODIUM			
VANADIUM			
ZINC			

COPCs — Chemicals of potential concern.
COCs — Chemicals of concern.

TABLE 2-4

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SURFACE WATER
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health		Ecological	
	COPCs	Risk Drivers	COPCs	Risk Drivers
Herbicides				
2,4-D			2,4-D	
Metals				
ALUMINUM				
ANTIMONY	ANTIMONY			
ARSENIC				
BARIUM				
CALCIUM				
COBALT			COBALT	
COPPER			COPPER	
IRON			IRON	
LEAD			LEAD	
MAGNESIUM				
MANGANESE			MANGANESE	
POTASSIUM				
SODIUM				
VANADIUM				
ZINC				
Filtered Metals				
ANTIMONY, FILTERED				
ARSENIC, FILTERED				
BARIUM, FILTERED				
CALCIUM, FILTERED				
COBALT, FILTERED				
COPPER, FILTERED				
IRON, FILTERED				
LEAD, FILTERED				
MAGNESIUM, FILTERED				
MANGANESE, FILTERED				
POTASSIUM, FILTERED				
SODIUM, FILTERED				

TABLE 2-4

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SURFACE WATER
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health		Ecological	
	COPCs	Risk Drivers	COPCs	Risk Drivers
Filtered Metals (Continued)				
VANADIUM, FILTERED				
ZINC, FILTERED				

COPCs — Chemicals of potential concern.

TABLE 2-5

SUMMARY OF POSITIVE ANALYTICAL RESULTS, COPCs, AND RISK DRIVERS FOR SURFACE WATER
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical Detected	Human Health			Ecological	
	COPCs	COCs	Risk Drivers	COPCs	Risk Drivers
Volatiles					
METHYLENE CHLORIDE					
Semi-Volatiles					
BENZO(B)FLUORANTHENE					
CHRYSENE					
FLUORANTHENE					
PYRENE					
Pesticides					
AROCLOR-1248	AROCLOR-1248			AROCLOR-1248	
Herbicides					
DINOSEB					
PENTACHLOROPHENOL					
Metals					
ALUMINUM	ALUMINUM			ALUMINUM	
ANTIMONY	ANTIMONY			ANTIMONY	
ARSENIC	ARSENIC	ARSENIC		ARSENIC	
BARIUM				BARIUM	
CALCIUM					
CHROMIUM					
COBALT					
COPPER				COPPER	
IRON	IRON	IRON		IRON	
LEAD					
MAGNESIUM					
MANGANESE	MANGANESE	MANGANESE		MANGANESE	
MERCURY					
NICKEL					
POTASSIUM					
VANADIUM				VANADIUM	
ZINC					

COPCs — Chemicals of potential concern.
COCs — Chemicals of concern.

TABLE 2-6

SUMMARY OF RISK DRIVERS FOR GROUNDWATER
SWMU 9 - PESTICIDE CONTROL/ R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical of Concern[1]	Impact on Human Receptors	Comments
GROUND WATER		
1,1-Dichloroethene	Residential ILCR = 7.5E-5	Risks from volatile chlorinated organics were based on the hypothetical future residential use of ground water. Risks from cis-1,2-DCE (detected in three of 12 samples) were based on the maximum detected concentration, and 1,1-DCE was detected in only one sample and the concentration was less than US EPA and IDEM MCLs.
cis-1,2-Dichloroethene	Adult resident HQ = 0.49, Child resident HQ = 1.8	
Trichloroethene	Adult resident HQ = 0.2, Child resident HQ = 0.66, Residential ILCR = 9.4E-6	
Dieldrin	Residential ILCR = 6.3E-6	Dieldrin was detected in 1 of 12 unfiltered ground water samples with the maximum concentration (0.03 µg/L) less than the IDEM default closure level for ground water (0.053 µg/L). Risks calculated for dieldrin are based on the hypothetical future residential use of ground water.
Arsenic	Adult resident HQ = 0.26, Child resident HQ = 0.89, Residential ILCR = 7.4E-5	Risks for arsenic are based on the hypothetical future residential use of ground water. The maximum concentration in ground water (4.6 µg/L) is less than the current (50 µg/L) and recently proposed (10 µg/L) MCLs. In addition, the concentrations of arsenic in ground water samples are similar to the concentrations in the upgradient well.
Iron	Adult resident HQ = 1.7, Child resident HQ = 6.0	Risks for iron are based on the hypothetical future residential use of ground water. Risks calculated for iron are not based on adverse health effects but rather on recommended daily allowances.
Manganese	Adult resident HQ = 10, Child resident HQ = 35	Risks for manganese are based on the hypothetical future residential use of ground water and assume exposure to the maximum detected concentration.

TABLE 2-6

SUMMARY OF RISK DRIVERS FOR GROUNDWATER
SWMU 9 - PESTICIDE CONTROL/ R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Chemical of Concern[1]	Impact on Human Receptors	Comments
GROUNDWATER (CONTINUED)		
Nickel	Adult resident HQ = 0.36, Child resident HQ = 1.3	Risks for nickel are based on the hypothetical future residential use of ground water. Only the risk for the future child resident slightly exceeds unity. All nickel concentrations in ground water are less than the IDEM closure level for Class I ground water.
SEDIMENT		
Arsenic	Recreational User ILCR = 3.0E-6, Child resdient HQ = 0.26, Residential ILCR = 1.5E-5	Risks (>1.0E-6) for arsenic in sediment are based on future land use scenarios. Although the maximum concentration (6.1 mg/kg) exceeded the concentration in the upgradient sample, the concentrations of arsenic in sediment are within naturally occurring levels in soil at the Base. Risks calculated for residnetial receptors are based on very conservative exposure assumptions. Risks from exposure to sediment are less than or within the US EPA's target risk range for all receptors.
Iron	Child resident HQ = 0.41	Risks for exposure to iron in sediment are based on the hypothetical future residential land use and conservative exposure assumptions but do not pose a risk under current land use. Risks calculated for iron are not based on adverse health effects but rather on recommended daily allowances.
Manganese	Child resident HQ = 0.24	Risks for exposure to manganese in sediment are based on the hypothetical future residential land use and conservative exposure assumptions but do not pose a risk under current land use.

1,1-DCE — 1,1-Dichloroethene.
cis-1,2-DCE — cis-1,2-Dichloroethene.
µg/L — micrograms per liter.
HI — hazard Indices.
HQ — Hazard Quotient.
IDEM — Indiana Department of Environmental Management.
ILCR — Incremental lifetime cancer risk.
MCLs — Maximum Contaminant Level Goals.
mg/kg — milligrams per kilogram.
US EPA — United States Environmental Protection Agency.

1 Any carcinogenic chemical with a ILCR of greater than 1.0E-6 or a noncarcinogenic chemical contributing to target organ HI greater than 1.0.

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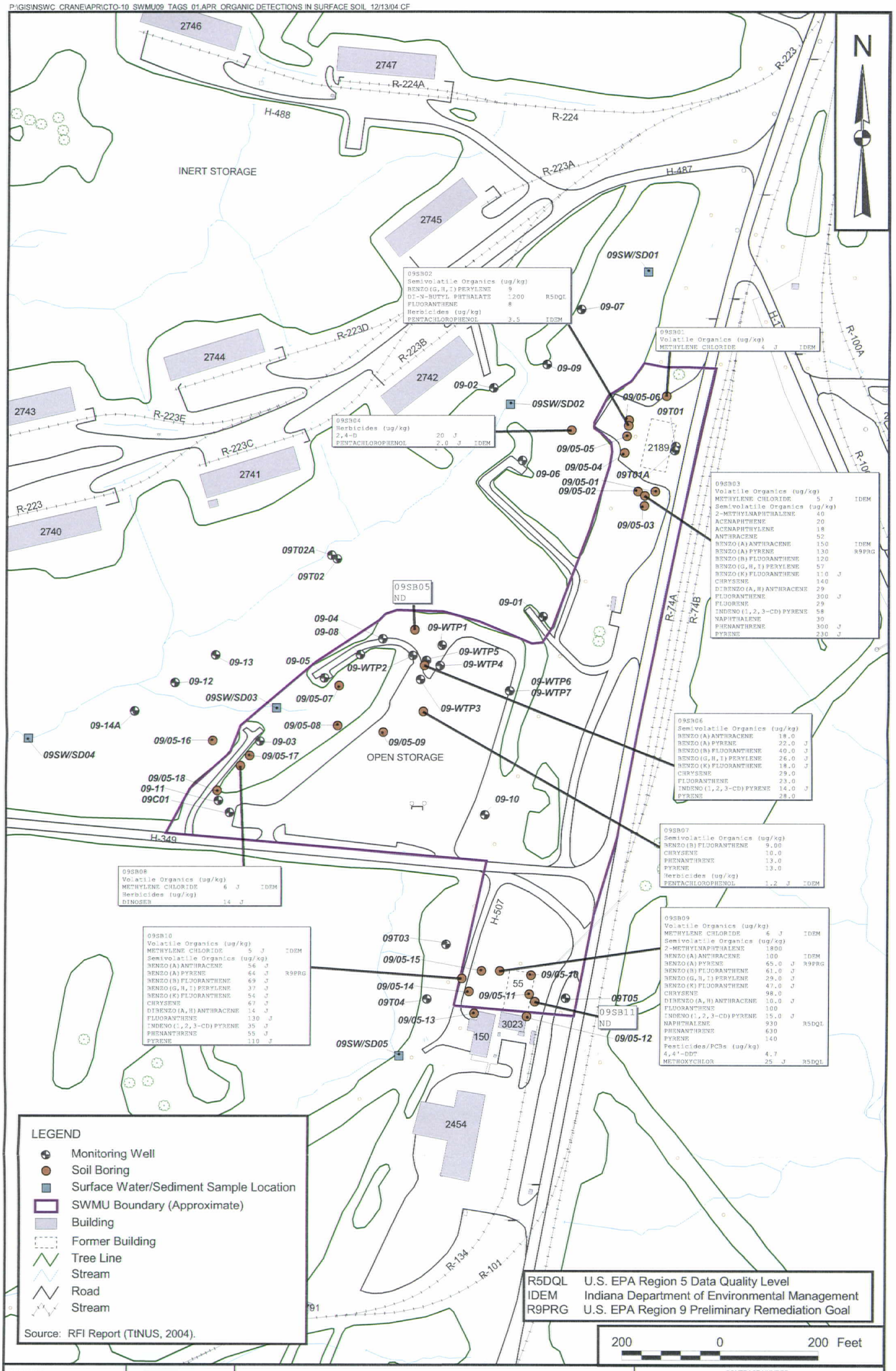

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CHECKED BY V. PLACHY	DATE 12/08/04	CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA	APPROVED BY — DATE —
COST/SCHEDULE-AREA		NSWC CRANE	APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC	CRANE, INDIANA	DRAWING NO. FIGURE 2 - 1 / REV 0

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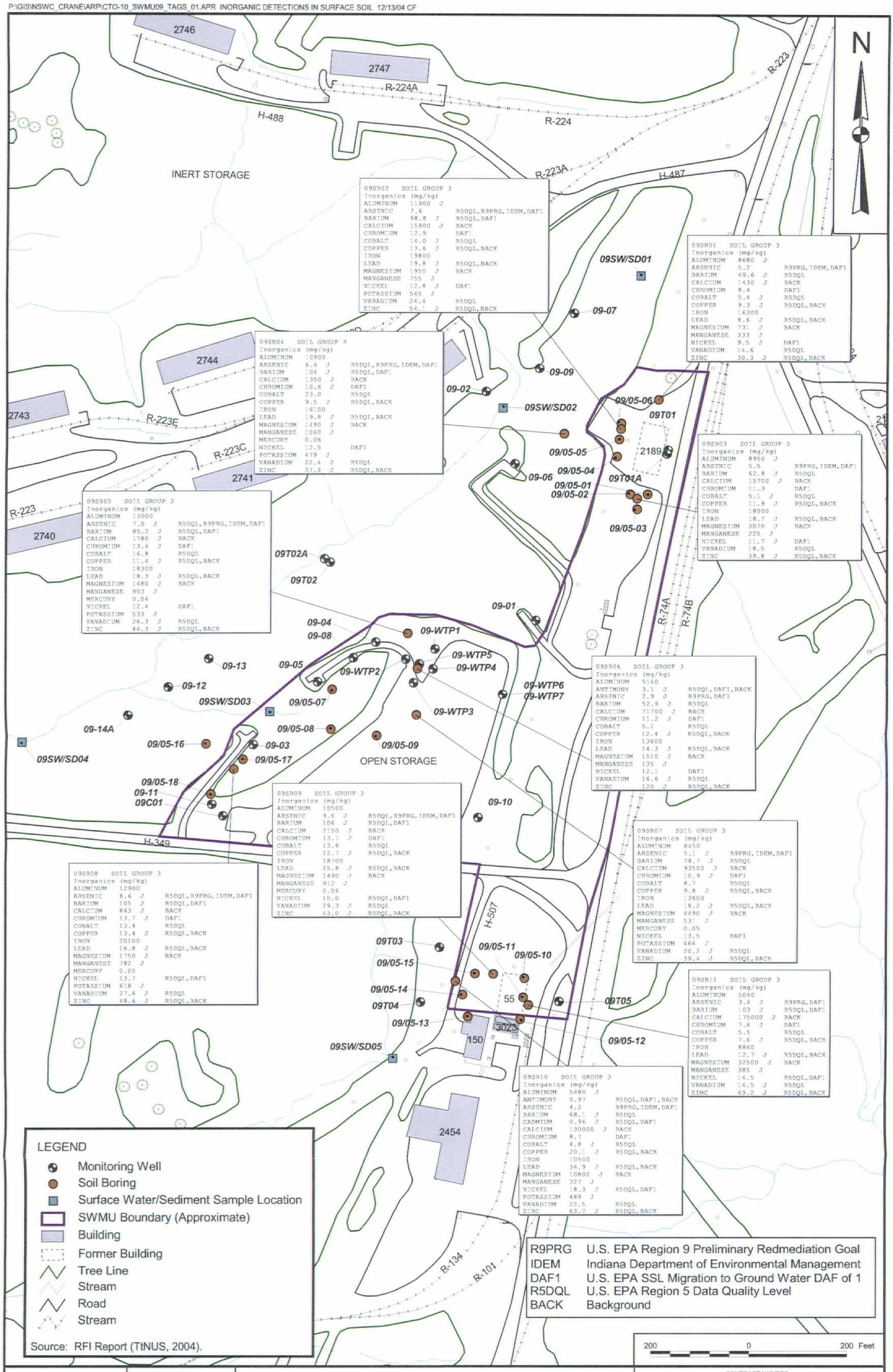

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SCALE	AS NOTED

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INORGANIC DETECTIONS IN SURFACE SOIL

CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
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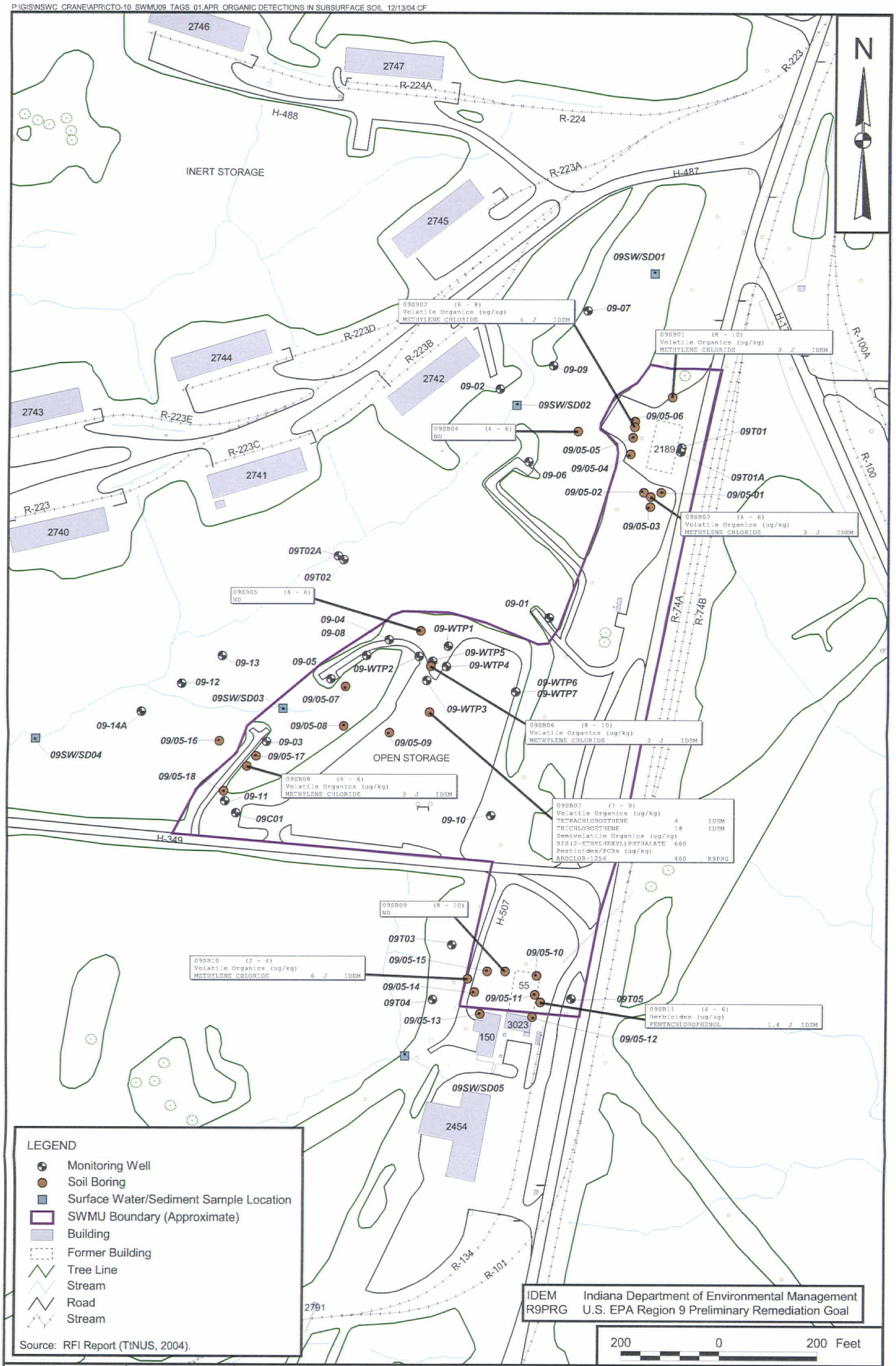

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CHECKED BY V. PLACHY	DATE 12/08/04		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
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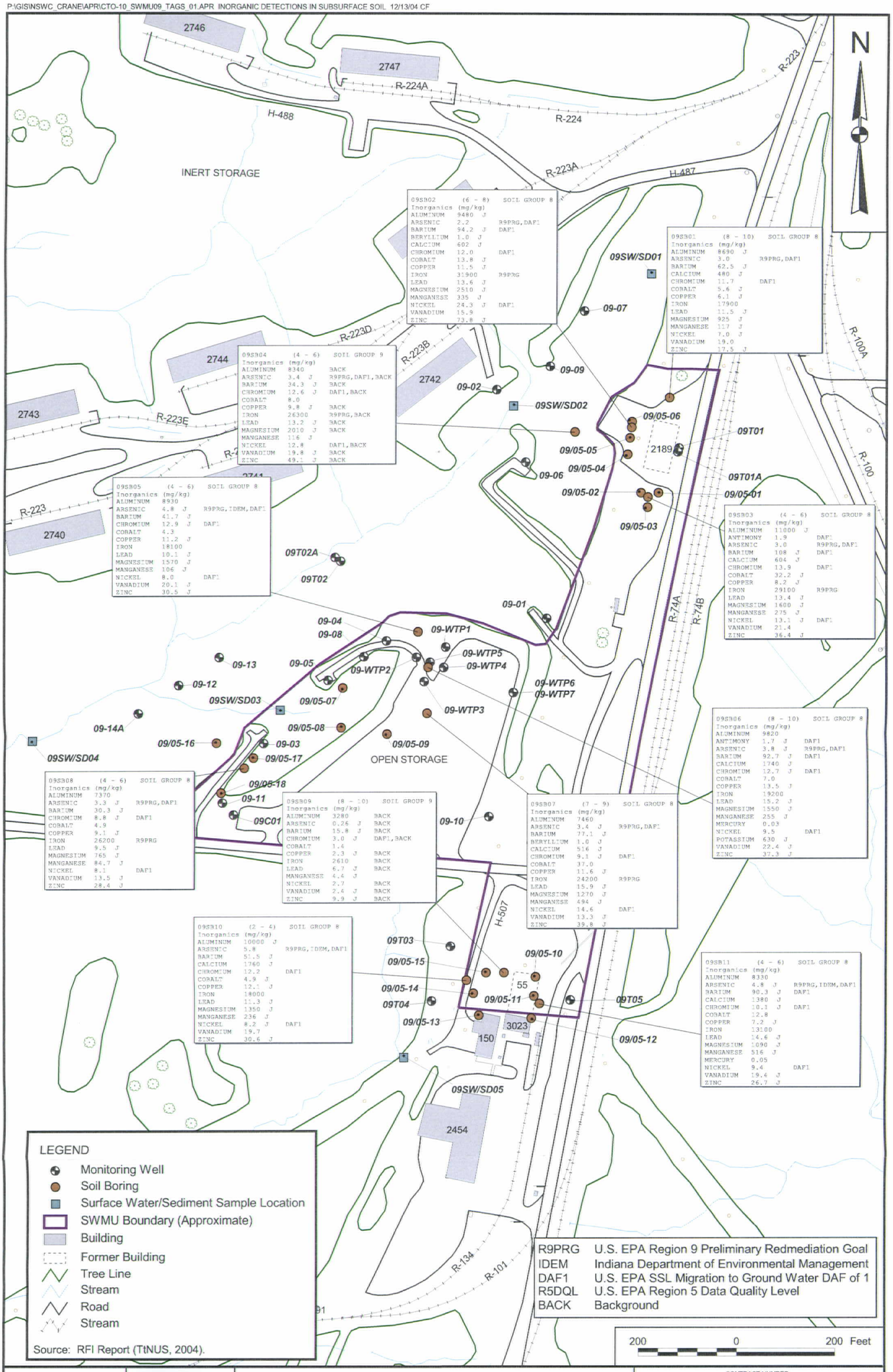

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K. PEILA	5/21/02
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V. PLACHY	12/08/04
COST/SCHEDULE-AREA	
SCALE	AS NOTED

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INORGANIC DETECTIONS IN SUBSURFACE SOIL

CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
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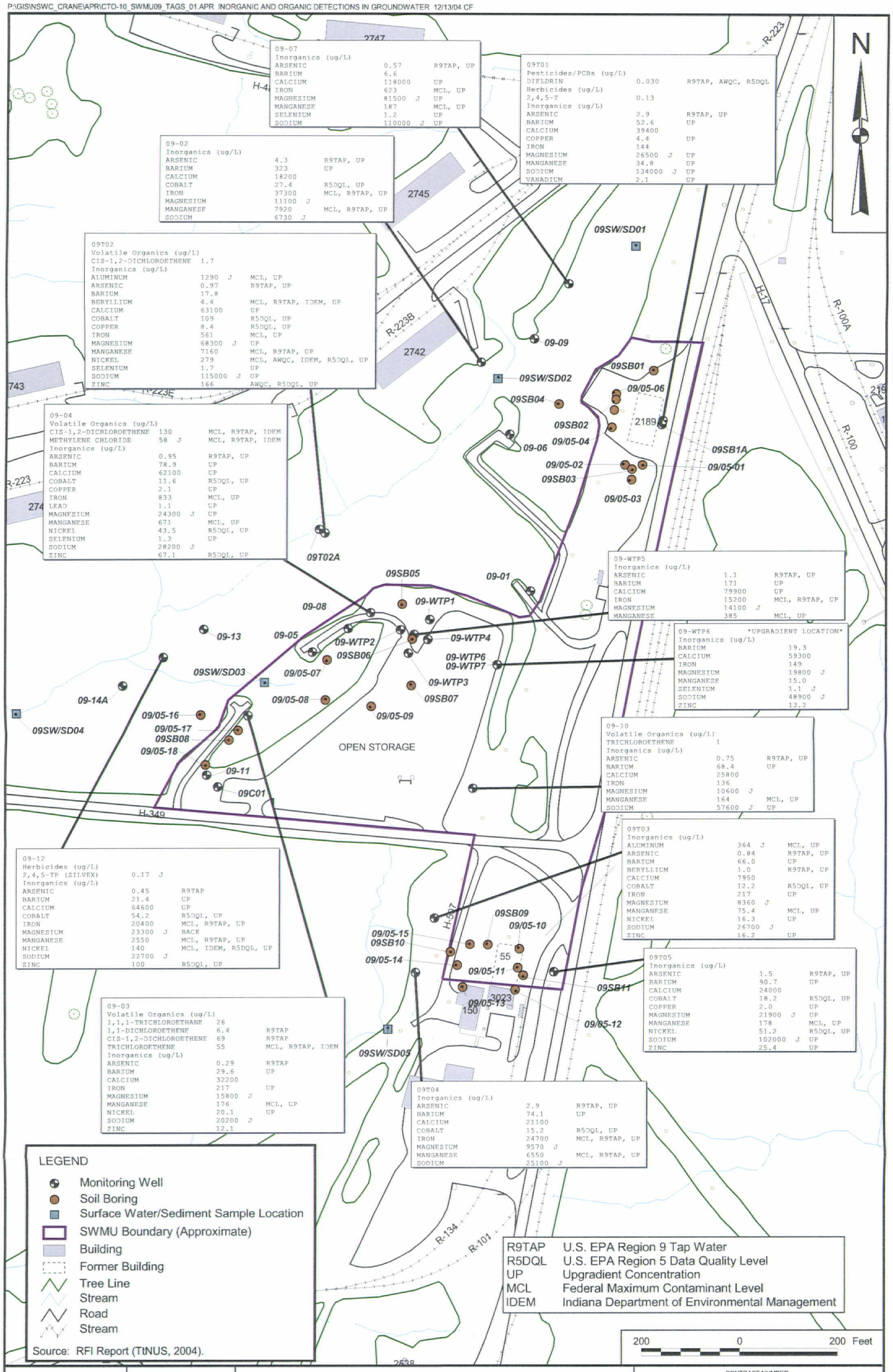

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V.PLACHY	12/08/04
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

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INORGANIC AND ORGANIC DETECTIONS IN GROUND WATER

CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
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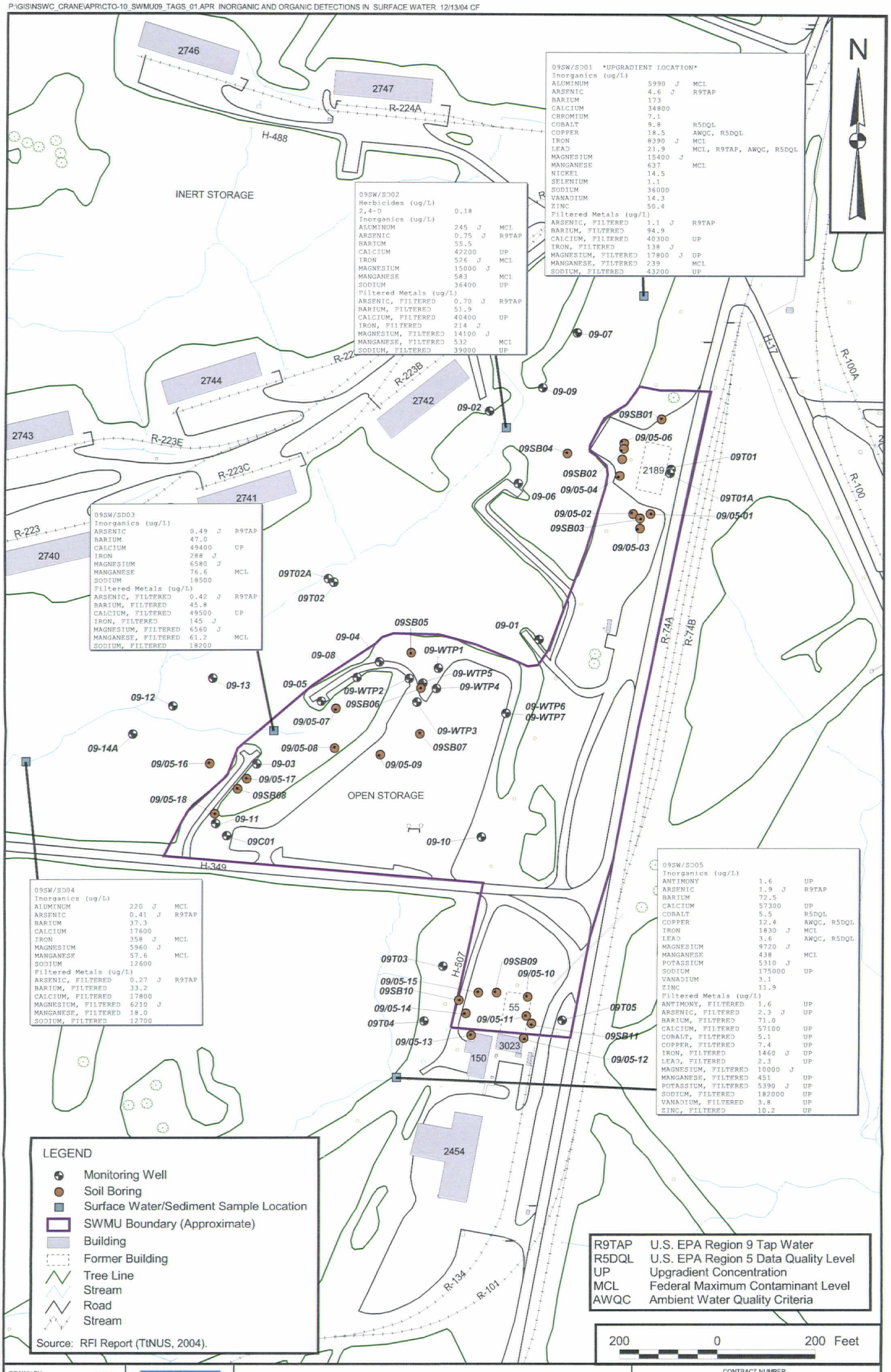

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V. PLACHY	12/08/04
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

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INORGANIC AND ORGANIC DETECTIONS IN SURFACE WATER

CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NSWC CRANE

CRANE, INDIANA

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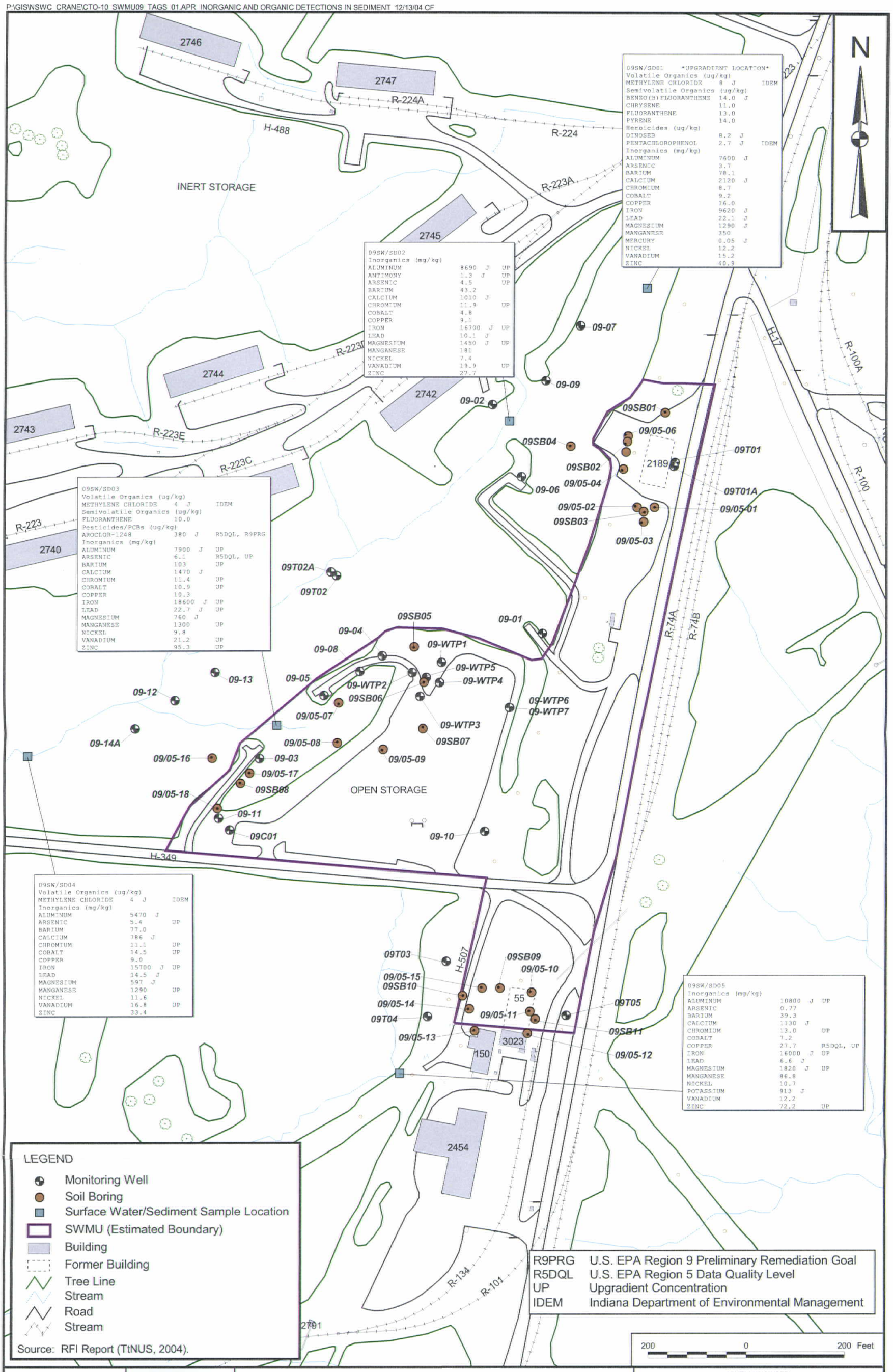

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K. PEILA	5/21/02
CHECKED BY	DATE
V. PLACHY	12/08/04
COST/SCHEDULE-AREA	
SCALE	AS NOTED

NAVFAC

INORGANIC AND ORGANIC DETECTIONS IN SEDIMENT

CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
N4267	
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3.0 DEVELOPMENT OF CORRECTIVE MEASURES OBJECTIVES

The purpose of this section is to identify ARARs and TBC criteria, and to develop corrective measures objectives for soil and groundwater. The corrective measures objectives are based on contaminant characterization, risk assessment, and compliance with risk-based and ARAR-based action levels.

3.1 ARARs

ARARs include the requirements, criteria, or limitations promulgated under the Federal and state law that address a chemical, location, or action at a site. The definition of ARARs is as follows:

- Any standard, requirement, criterion, or limitation under Federal environmental law.

- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-citing law that is more stringent than the associated Federal standard, requirement criterion, or limitation.

- One of the primary concerns during the development of corrective measures objectives is the degree of human health and environmental protection afforded by a given remedy. Consideration should be given to remedies that attain or exceed ARARs.

Definitions of the two types of ARARs, as well as TBC criteria, are given below:

- Applicable Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

- Relevant and Appropriate Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that, while not "applicable", address problems or situations sufficiently similar (relevant) to those encountered at a site such that their use is well suited (appropriate) to the particular site.

- TBC Criteria are non-promulgated, enforceable guidelines or criteria that may be useful for developing remedial actions or necessary for determining what is protective of human health and/or

the environment. Examples of TBC criteria include U.S. EPA Drinking Water Advisories and Risk-Based Concentrations (RBCs).

ARARs fall into three categories, based on the manner in which they are applied:

- Contaminant Specific – These include health/risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples of contaminant-specific ARARs include Maximum Contaminant Levels (MCLs) and the Clean Water Act (CWA).

- Location Specific – These restrictions are based on the concentration of specific contaminants or the conduct of activities in specific locations. These may restrict or preclude certain remedial actions or may apply only to certain portions of a site.

- Action Specific – These are technology- or activity-based controls or restrictions on activities related to management of contaminants. Action-specific ARARs pertain to implementing a given remedy.

A summary listing of all contaminant-, location-, and action-specific ARARs and TBCs for SWMU 9 are listed in Tables 3-1, 3-2, and 3-3, respectively. Sections 3.1.2.1, 3.1.2.2, and 3.1.2.3 provide a brief description of each contaminant-, location-, and action-specific ARAR and TBC shown in Tables 3-1 through 3-3.

3.1.1 Contaminant-Specific ARARs and TBC Criteria

The Safe Drinking Water Act (SDWA) [40 CFR Parts (§§)141-143] promulgated National Primary Drinking Water Standard MCLs [40 CFR Part (§)141]. MCLs are enforceable standards for contaminants in public drinking water supply systems. They consider not only health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary MCLs (SMCLs) (40 CFR §143) are not enforceable but are intended as guidelines for contaminants that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and may deter public acceptance of drinking water provided by public water systems.

The SDWA also established MCL Goals (MCLGs) for several organic and inorganic compounds in drinking water. MCLGs indicate the level of contaminants in drinking water at which no known or anticipated health effects would occur, allowing for an adequate margin of safety. MCLGs are non-enforceable public health goals. The National Contingency Plan (NCP) [40 CFR §300.430(e)(2)(i)] states that MCLGs that are set at levels greater than zero shall be attained by remedial actions for

groundwater or surface waters that are current or potential sources of drinking water where MCLs are relevant and appropriate to the circumstances of the release.

CWA National Pollutant Discharge Elimination System (NPDES) (40 CFR §122) specifies that NPDES permits are required for any discharge to surface water. CMAs that include discharges to surface water would have to comply with the permit requirements. The CWA is a TBC criterium.

U.S. EPA Health Advisories are non-enforceable guidelines developed by the U.S. EPA Office of Drinking Water for contaminants that may be intermittently encountered in public water supply systems. Health advisories are available for short-term, longer-term, and lifetime exposures for a 10-kilogram (kg) child and a 70-kg adult. Health advisories may be pertinent for remedial action/corrective measures involving groundwater, especially for contaminants that are not regulated by the SDWA. U.S. EPA health advisories are TBC criteria.

Reference Doses (RfDs), as defined in the U.S. EPA Integrated Risk Information System (IRIS), are an estimate (with uncertainty spanning perhaps an order of magnitude) of daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are developed for chronic and/or subchronic human exposure to hazardous chemicals and are based on the assumption that thresholds exist for certain toxic effects. The RfD is usually expressed as an acceptable dose [milligram (mg)] per unit body weight (kg) per unit time (day). The RfD is derived by dividing the no-observed-adverse effect level (NOAEL) or the lowest-observed-adverse effect level (LOAEL) by an uncertainty factor (UF) times a modifying factor (MF). RfDs are TBC.

U.S. EPA Carcinogenic Slope Factors, as defined in the IRIS, are an upper bound, approximating a 95 percent confidence limit, on the increased cancer risk from a lifetime exposure to a contaminant. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100. Carcinogenic slope factors are TBC criteria.

U.S. EPA Region 9 Primary Remediation Goals (PRGs) are risk-based concentrations, derived from standardized equations combining exposure information assumptions with U.S. EPA toxicity data for contaminants in soil, air, and drinking water. They are considered to be protective for humans (including sensitive groups) over a lifetime. However, PRGs are not always applicable to a particular site and do not address non-human health endpoints such as ecological impacts. PRGs are not de facto cleanup standards; however, they could be used to establish final cleanup levels for a site after a proper evaluation takes place. Region 9 PRGs are risk-based concentrations that are intended to assist risk

assessors and others in initial screening-level evaluations of environmental measurements. PRGs are TBC.

IDEM Risk Integrated System of Closure (RISC) is a non-rule policy that incorporates environmental risk assessment principles to protect human health and the environment and achieve consistent closure of contaminated soil and groundwater. As a non-rule policy document, RISC guidance does not have the effect of law. However, the policy provides a systematic approach for consistently and rationally implementing the laws and rules that govern site investigation and closure. Included in this policy are risk-based closure level constituent concentrations calculated to be protective of human health. The RISC is a TBC criterium.

Indiana Water Quality Standards (IWQS) (IAC 327) establish minimum standards for the protection of surface water quality. IDEM has established two sets of water quality criteria; one for bodies of water that are in the Great Lakes Basin and another for all other state bodies of water. Each set of criteria includes values for the protection of human health, aquatic life, and wildlife. There are two categories of human health criteria: drinking and non-drinking. The drinking water criteria apply to the point of intake. Separate human health cancer and non-cancer criteria are derived if the contaminant has the potential to cause cancer. The value of the highest level of protection is used for each contaminant. Water from SWMU 9 does not drain to the Great Lakes Basin. IWQS are ARARs.

3.1.2. Location-Specific ARARs and TBC Criteria

Endangered Species Act of 1973 (16 USC 1531) (50 CFR §17) provides to conserve the ecosystems upon which endangered and threatened species depend and to conserve and recover listed species. Corrective measure actions, if required, would need to be conducted in a manner such that the continued existence of any endangered or threatened species is not jeopardized or its critical habitat is not adversely affected. Consultation with the U.S. Fish and Wildlife Service is also required. SWMU 9 is located in Martin County. The State of Indiana has identified a list of endangered, threatened, and rare species for Martin County. The species include plants, insects, birds, reptiles, and birds. In addition, migrating species may move through the area. The Endangered Species Act of 1978 is potentially applicable.

U.S. EPA Groundwater Protection Strategy and Classification Guidelines (U.S. EPA, 1984) are policies to protect groundwater for its highest present or potential beneficial use. The strategy designates three classifications of groundwater:

- Class I – Special Groundwater: water that is highly vulnerable to contamination and is either irreplaceable or ecologically vital sources of drinking water.

- Class II – Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses: waters that are currently used or that are potentially available.

- Class III – Groundwater Not a Potential Source of Drinking Water and of Limited Beneficial Use. Class III groundwater units are further subdivided into two subclasses.

  - Subclass IIIA includes groundwater units that are highly to intermediately interconnected to adjacent groundwater units of a higher class and/or surface waters. They may, as a result, be contributing to the degradation of the adjacent waters. They may be managed at a similar level as Class II groundwater, depending on the potential for producing adverse effects on the quality of adjacent waters.

  - Subclass IIIB is restricted to groundwater characterized by a low degree of interconnection to adjacent surface waters or other groundwater units of a higher class within the Classification Review Area. These groundwaters are naturally isolated from the source of drinking waters in such a way that little potential exists for producing adverse effects on quality. They have low resource values outside of mining or waste disposal.

At SWMU 9, groundwater is likely considered to be Class IIIA. However, a potential future residential land use has been evaluated in the RFI, although unlikely; therefore, the groundwater can be considered as Class II. The U.S. EPA groundwater protection strategy and classification guidelines are TBC criteria.

<u>The Fish and Wildlife Coordination Act (FWCA)</u> (16 U.S.C. §§661-667e, March 10, 1934, as amended 1946, 1958, 1978, and 1995) provides that whenever the waters or channel of a body of water are modified by a department or agency of the U.S., the department or agency first will consult with the U.S. Fish and Wildlife Service and with the head of the agency exercising administration over the wildlife resources of the state where construction will occur, with a view to the conservation of wildlife resources. The Act provides that land, water and interests may be acquired by federal construction agencies for wildlife conservation and development. In addition, real property under jurisdiction or control of a federal agency and no longer required by that agency can be utilized for wildlife conservation by the state agency exercising administration over wildlife resources upon that property.

FWCA provides the basic authority for the Fish and Wildlife Service's involvement in evaluating impacts to fish and wildlife from proposed water resource development projects. It requires that fish and wildlife resources receive equal consideration to other project features. It also requires that Federal agencies that construct, license, or permit water resource development projects must first consult with the Fish and Wildlife Service (and the National Marine Fisheries Service in some instances) and State fish and wildlife agency regarding the impacts on fish and wildlife resources and measures to mitigate these impacts. Full consideration is to be given to Fish and Wildlife Service recommendations. The FWCA is an ARAR.

The Archaeological and Historic Preservation Act (AHPA) provides for the preservation of historical and archeological data (including relics and specimens) which might otherwise be irreparably lost or destroyed as the result of:

1) Flooding, the building of access roads, the erection of workmen's communities, the relocation of railroads and highways, and other alterations of the terrain caused by the construction of a dam by any agency of the United States, or by any private person or corporation holding a license issued by any such agency or,

2) Any alteration of the terrain caused as a result of any Federal construction project or federally licensed activity or program.

The purposes of the AHPA are to recognize the vital contribution of our wildlife resources to the nation and their increasing public interest and significance, and to provide that wildlife conservation receive equal consideration and be coordinated with other features of water-resource development programs through planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. In furtherance of the stated purposes, the U.S. Secretary of the Interior (Secretary) is authorized to provide assistance to, and cooperate with, Federal, state, and public or private agencies and organizations in:

- Developing, protecting, rearing, and stocking all species of wildlife, resources thereof, and their habitat; controlling losses from disease or other causes; minimizing damages from overabundant species.

- Providing public shooting and fishing areas, including easements across public lands; carrying out other necessary measures.

The Secretary is also authorized to make surveys and investigations of the wildlife of the public domain, including lands and waters or interest acquired or controlled by an agency of the United States, and to

accept donations of land and contributions of funds in furtherance of the purposes of AHPA. The AHPA is an ARAR.

Federal Protection of Wetlands Executive Order (EO) 11990 authorizes federal protection of wetlands. The order requires federal agencies to consider the potential effects of a proposed project on the survival and quality of wetlands including the conservation and long term productivity of existing faunal species and habitat diversity and stability. EO 11990 applies to the issuance by federal agencies of permits, licenses, or allocations to private parties for activities involving wetlands on federal lands.

The purpose of EO 11990 is to "minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands." To meet these objectives, EO 11990 requires federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. EO 11990 applies to:

- Acquisition, management, and disposition of federal lands and facilities construction and improvement projects which are undertaken, financed, or assisted by federal agencies.
- Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities.

EO 11990 is an ARAR.

Bald and Gold Eagle Protection Act (BGEPA) (16 §USC 668a-d) prohibits any form of possession or taking of both bald and golden eagles. The statute imposes criminal and civil sanctions as well as an enhanced penalty provision for subsequent offenses. Further, the BGEPA provides for the forfeiture of anything used to acquire eagles in violation of the statute. The statute accepts from its prohibitions on possession the use of eagles or eagle parts for exhibition, scientific, and Indian religious uses. The BGEPA is an ARAR.

Indiana Non-game and Endangered Species Conservation Act (IESA) (IC 14-22-34) provides a list of those species and subspecies of wildlife indigenous to Indiana which are determined to be endangered in Indiana. In addition, this rule governs the taking, possession, removal, capture, destruction, and management of state listed endangered species. The IESA is an ARAR.

Indiana Wildlife Regulation (IWR) (IC 14-22-10) provides protection for wildlife from releases or discharges of contaminants or waste materials into state waters or land that may result in the destruction

of wild animals. The state Department of Natural Resources has the authority and responsibility to protect and properly manage the fish and wildlife resources of the state. The release of contaminated waste during the remedy activity could be released on to soil and possibly result in discharge to state waters. The IWR is an ARAR.

Indiana Natural Heritage Protection Campaign (IC 14-31-2) promotes the preservation of areas of unusual natural interest for scientific, educational, recreational, cultural, and aesthetic purposes as a link to the Indiana's past and future. The rule also provides for the maintenance and management of those natural areas and the rare native species for which the areas are habitat. Remedy activities at SWMU 9 may result in disturbance of natural areas inhabited by Indiana rare species. The Indiana Heritage Protection Campaign is an ARAR.

3.1.3 Action-Specific ARARs and TBC Criteria

Clean Air Act (CAA) (40 CFR §50) contains two programs or requirements that may be ARARs: National Ambient Air Quality Standards (NAAQS) (40 CFR §§ 50 and 53) and National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR §61). NESHAPs, which are emission standards for source types (i.e., industrial categories) that emit hazardous air pollutants, are not likely to be applicable or relevant because they were developed for specific contaminants and sources. U.S. EPA requires the attainment and maintenance of primary and secondary NAAQS to protect public health and public welfare. These standards are contaminant and averaging-period-specific national limitations on ambient air quality. States are responsible for assuring compliance with the NAAQS. NAAQS and NESHAPs are ARARs.

CWA NPDES (40 CFR §122) specifies that NPDES permits are required for any discharge to surface water. CMAs that include discharges to surface water would have to comply with the permit requirements. The CWA is an ARAR.

RCRA Solid Waste Management Regulations (40 CFR §258) provides for design and operating standards for solid waste (nonhazardous) landfills. CMAs that include solid waste landfills or where nonhazardous soil is stockpiled or disposed on site would have to comply with RCRA.

RCRA (40 CFR §261) provides for regulations that govern the procedures for identifying if a material is a hazardous waste. CMAs at SWMU 9 have the potential to generate specific materials that may be classifiable as a characteristic or listed hazardous waste.

RCRA standards are applicable to generators of hazardous wastes (40 CFR §262). CMAs at SWMU 9 have the potential to generate waste for removal that may be determined to be hazardous.

Generated wastes that are determined to be hazardous and transportation off-site are regulated under RCRA (40 CFR §263).

RCRA regulations are applicable to owners and operators of hazardous waste TSD facilities as standards and interim standards (40 CFR §§264 and 265). These regulations would be applicable to waste removed from this site including both on-site and off-site management; however, the reuse of treated soils as backfill would not be subject to the disposal facility standard.

RCRA Land Disposal Restrictions (LDRs) (40 CFR §268) identifies hazardous wastes that are restricted from land disposal and waste analysis requirements. CMAs at SWMU 9 may include the treatment or disposal of contaminated soils/wastes and/or treatment residuals that may be considered hazardous wastes are subject to land disposal restrictions.

The RCRA is an ARAR.

Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR §107 and §§171 to 179) regulate the transportation of hazardous materials including requirements that regulate packaging, marking, labeling, and transportation methods. CMAs at SWMU 9 have the potential to generate off-site shipments of contaminated waste including soil that could be classified as a hazardous material. The DOT rules for the transportation of hazardous materials are ARARs.

Indiana Environmental Remediation Act (IERA) (IC 13-30-10) requires certain environmental remediation plans to specify remediation objectives based on specified factors. The IERA directs IDEM to certify completion of plans and to issue covenants not to sue with respect to completed plans. The IERA is an ARAR.

Indiana Solid Waste Management Board (ISWMB) (329 IAC) provides for design and operating standards for solid waste (nonhazardous) landfills. Additionally, Indiana adopted regulations identical to the Federal regulations for the listing of hazardous waste (40 CFR §261), generators of hazardous wastes (40 CFR §262), and transporters of hazardous wastes (40 CFR §263). Additionally, Indiana adopted regulations identical to the Federal standards and interim standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities (40 CFR §§264 and 265). These regulations are ARARs.

Indiana Air Screening Levels (IASLs) (325 IAC) and Ambient Air Quality Standards (IAAQS) (326 IAC) are two state requirements that may be ARARs or TBC criteria. IASLs are non-rule guidelines that are used by IDEM to evaluate the ambient impact of hazardous contaminants. When determining a pollutant's maximum allowable concentration, the toxicity of a compound is measured by its permissible exposure limit (PEL). The PEL is the maximum concentration under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effects. The PEL for each chemical is determined by the Occupational Safety and Health Administration (OSHA). IDEM calculates IASLs as generally 0.5 percent of the PEL. If the maximum air concentration is less than the ASL, it indicates that there should not be a significant impact on public health and welfare. Site specific exceptions may be made.

The purpose of the IAAQS is to establish primary and secondary ambient air quality standards for the state and, to the extent necessary, to protect the public health and welfare. IAAQS are in accordance with the provisions of the CAA. 326 IAC provides air quality standards for carbon monoxide, lead, nitrogen oxides, particulate matter, ozone, and sulfur oxides emitted from a major source of emissions.

IASLs are TBC criteria. IAAQS are ARARs.

Indiana Water Pollution Control Board (IWPCB) (327 IAC) provides for NPDES permits requirements for any discharge to surface water. The IWPCB regulations are ARARs.

3.2 MEDIUM-SPECIFIC CORRECTIVE ACTION OBJECTIVES

Table 3-4 summarizes the receptor-specific human risks, the hazards and ecological risks, and recommendations from the RFI Report for SWMU 9 (TtNUS, 2004).

3.2.1 Soils

Human Health Risk

As detailed in Section 2.1.1.1, there are no significant potential health risks for human receptors as determined under current land use and future use for surface soils (TtNUS, 2004); therefore, surface soil will not be carried forward.

Ecological Risk

As detailed in Section 2.1.1.2, there are no significant potential risks to plants, invertebrates, mammals, and birds from chemicals in surface soil (TtNUS, 2004); therefore, surface soil will not be carried forward.

3.2.2 Groundwater

Human Health

CAOs are developed in this section to address contaminated groundwater at SWMU 9. CAOs generally identify COCs, receptors, pathways, and ACLs. The RFI for SWMU 9 concluded that iron and manganese detected in SWMU 9 groundwater at concentrations greater than upgradient concentrations would have significant risks associated with the future adult resident. The RFI for SWMU 9 concluded that cis-1,2-DCE, iron, manganese, and nickel detected in SWMU 9 groundwater at concentrations greater than upgradient concentrations would have significant risks associated with the future child resident.

The medium-specific CAOs for contaminated groundwater are as follows:

- Prevent human exposure (ingestion) to contaminated groundwater with concentrations greater than the Media Cleanup Standards (MCS).
- Comply with chemical-specific, location-specific, and action-specific ARARs and TBC guidance.

3.3 CHEMICALS OF CONCERN

3.3.1 Groundwater

As discussed in Section 2.1.3,

- Ingestion of groundwater containing cis-1,2-DCE is a risk driver for the future child resident.
- Ingestion of iron and manganese is a risk driver for the future adult and child resident.
- Ingestion of groundwater containing nickel and dermal contact with groundwater containing manganese are risk drivers for the future child resident.

3.4 MEDIA CLEANUP STANDARDS

3.4.1 Groundwater

Human Health Risk

MCSs have been developed for human health risk drivers in groundwater at SWMU 9 and are shown in Table 3-5.

The human health groundwater MCSs for SWMU 9 was back calculated from the risk assessment included in the RFI for SWMUs 4, 5, 9, and 10 according to the methodology used by U.S. EPA Region 9 in the development of its PRGs. Because risk assessment equations are linear in the concentration term, an acceptable remediation concentration for the site can be calculated using a ratio of the site concentration to the resulting risk estimate which was determined in the risk assessment for utilizing a target cancer risk (TCR) or Target Hazard Index (THI). Because the chemicals of concern for SWMU 9 (cis,1,2-dichloroethene, iron, manganese, and nickel) are classified as noncarcinogenic, a THI of unity (1) is employed to determine the remediation concentration. An example calculation is provided below.

The groundwater MCS was calculated by the following equation:

$$MCS = \frac{Cgw \times THI}{Risk}$$

Where:

MCS	=	Media Cleanup Standard (µg/L)
Cgw	=	Groundwater exposure point concentration used in the SWMU 9 risk assessment (µg/L)
THI	=	Target Hazard Index
Risk	=	Groundwater risk for manganese calculated in the SWMU 9 Risk assessment (µg/L)

Example Calculation: Residential groundwater MCS for manganese

Cgw	=	7,920 µg/L
THI	=	1
Risk	=	10.2 (ingestion + dermal HI)

$$MCS = \frac{7{,}920 \times 1}{10.2}$$

MCS (manganese) = 775 µg/L

3.5 VOLUME OF CONTAMINATED MEDIA

In this section, estimates of contaminated media are developed for use in evaluation of corrective measure alternatives that may be used to remediate groundwater at SWMU 9.

3.5.1 Groundwater

To protect the future adult and child residents, remediation of manganese groundwater will need to occur. Appendices A.1, A.2, and A.5 present the basis and the calculations utilized to develop the groundwater remediation estimates.

TABLE 3-1

SUMMARY OF CONTAMINANT-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 – PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
FEDERAL				
Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs) Secondary MCLs (SMCLs) MCL Goals (MCLGs)	42 USC 300f et seq 40 CFR §§141 to 143	MCLs are relevant and appropriate; SMCLs and MCLGs are TBC	MCLs, SMCLs, and MCLGs established under this act are health-based limits for certain chemical substances in drinking water	Can be used for determining PRGs for groundwater.
Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC)	33 USC 1251 et seq. Section 304(a)(1)	TBC Criteria	Water-quality criteria are non-enforceable guidance and are used in conjunction with the designated use for a stream segment to establish water quality standards under CWA 303.	During remedial activities, groundwater or treatment by-products may be collected. Can be used to determine discharge limits or PRGs for surface water.
U.S. EPA Health Advisories	EPA 822-B-96-002	TBC Criteria	EPA Office of Drinking Water guidelines for chemicals that may be encountered in public water supply systems	Can be used for determining PRGs for groundwater
Reference Doses (RfDs) from Integrated Risk Information System (IRIS)	NA	TBC Criteria	EPA Office of Research and Development guidelines used in the public health assessment	Can be used for determining risk-based PRGs.
U.S. Carcinogenic Slope Factors from IRIS	NA	TBC Criteria	EPA Environmental Criteria and Assessment Office; EPA Carcinogen Assessment Group guidelines used in the public health assessment	Can be used for determining risk-based PRGs.

TABLE 3-1

SUMMARY OF CONTAMINANT-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 – PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
U.S. EPA Region 9 PRGs	NA	TBC Criteria	EPA Region 9 has developed primary remediation goals (PRGs) for contaminants in soil, air, and tap water. These are risk-based concentrations are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements	Can be used for determining PRGs.
STATE				
Indiana Department of Environmental Management (IDEM) Risk Integrated System of Closure (RISC) http://www.in.gov/idem/land/risc/techguide/riscguidance.pdf	NA	TBC Criteria	A non-rule policy that incorporates environmental risk assessment principles to protect human health and the environment and achieve consistent closure of contaminated soil and groundwater.	TBC in risk assessment
IDEM Water Quality Standards Applicable to All State Waters Except Waters of the State Within the Great Lakes System	327 IAC Article 2	Relevant and Appropriate	Establishes final acute value (FAV) in the undiluted discharge or the acute aquatic criterion (AAC), continuous criterion concentrations (CCCs), chronic aquatic criterion (CAC) to protect aquatic life from chronic toxic effects, terrestrial life cycle safe concentration (TLSC) to protect terrestrial organisms from toxic effects, human life cycle safe concentration (HLSC) to protect human health from toxic effects for state waters	During remedial activities, groundwater or treatment by-products may be collected. Can be used to determine discharge limits for surface water.

TABLE 3-2

SUMMARY OF LOCATION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
FEDERAL				
Endangered Species Act of 1973	16 USC 1531 50 CFR §§17 and 402	Relevant and Appropriate	Requires federal agencies to ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the future existence or critical habitat of any endangered or threatened species.	The Indiana Bat and several bird species are either endangered, threatened or species of special interest may reside in the vicinity of SWMU 9. In addition, migrating species may occasionally move through the area.
U.S. EPA Groundwater Protection Strategy and Classification Guidelines	NA	TBC Criteria	Provides guidance in determining the potential beneficial uses of contaminated groundwater.	Groundwater at SWMU 9 is classified as a shallow bedrock acquifer.
The Fish and Wildlife Coordination Act of 1934, as amended 1946, 1958, 1978 and 1995	16 USC 611 16 U.S.C. 661-667e; the Act of March 10, 1934; Ch. 55; 48 Stat. 401	Relevant and Appropriate	Requires federal agencies to consult with appropriate state agencies before discharging pollutants or dredge and fill material into a body of water of wetlands	Aquatic habitats have been identified at Crane.
The Archaeological and Historic Preservation Act	16 USC 469 36 CFR §65	Relevant and Appropriate	Establishes requirements relating to potential loss or destruction of significant scientific, historical, or archeological data as a result of a proposed remedy.	Artifacts may be discovered during site work.
Federal Protection of Wetlands Executive Order	Executive Order (EO) 11990 40 CFR 6 Appendix A	Relevant and Appropriate	Requires the action of federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance the natural and beneficial values of wetlands	Applicable where there are wetlands at or near the SWMU.

TABLE 3-2

SUMMARY OF LOCATION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
Bald and Gold Eagle Protection Act	(16 U.S.C. §§ 668a-668d, 54 Stat. 250) as amended -- Approved June 8, 1940, and amended by P.L 86-70 (73 Stat 143) June 25, 1959, P.L 87-884 (76 Stat. 1346) October 24, 1962; P.L. 92-535 (86 Stat. 1064) October 23, 1972; and P.L. 95-616 (92 Stat. 3114) November 8, 1978.	Relevant and Appropriate	Prohibitions. The Act imposes criminal and civil penalties on anyone (including associations, partnerships and corporations) in the U.S. or within its jurisdiction who, unless excepted, takes, possesses, sells, purchases, barters, offers to sell or purchase or barter, transports, exports or imports at any time or in any manner a bald or golden eagle, alive or dead; or any part, nest or egg of these eagles; or violates any permit or regulations issued under the Act. The definition of "take" includes pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb. The definition of "transport" includes convey or carry by any means; also deliver or receive for conveyance.	Applicable where that there are Bald Eagle nesting or habitat which might be disturbed during CMA at or near the SWMU.

TABLE 3-2

SUMMARY OF LOCATION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
STATE				
Indiana Non-game and Endangered Species Conservation	IC 14-22-34	Relevant and Appropriate	Establishes a list of those species and subspecies of wildlife indigenous to Indiana which are determined to be endangered in Indiana In addition, this rule governs the taking, possession, removal, capture, destruction, and management of state listed endangered species.	The State of Indiana has identified a list of endangered, threatened, and rare species for Martin County including the Indiana Bat and Bald Eagle. The species include plants, insects, birds, reptiles, birds, and, migrating species that may move through or live in the SWMUs These threatened or species of special interest that may reside in the vicinity of the SWMUs. In addition, migrating species may occasionally move through the area
Indiana Wildlife Regulation	IC 14-22-10	Relevant and Appropriate	Establishes protection for wildlife from releases or discharges of contaminants or waste materials into state waters or land that may result in the destruction of wild animals. The state Department of Natural Resources has the authority and responsibility to protect and properly manage the fish and wildlife resources of the state.	Any release of contaminated waste during the remedy activity that could be released on to soil and possibly result in discharge to state waters and result in harm to wild animals would have to comply with these requirements.
Indiana Natural Heritage Protection Campaign	IC 14-31-2	Relevant and Appropriate	Promotes the preservation of areas of unusual natural interest for scientific, educational, recreational, cultural, and aesthetic purposes as a link to the Indiana's past and future. The rules also provides for the maintenance and management of those natural areas and the rare native species for which the areas are habitat.	Remedy activities at SWMUs may result in disturbance of natural areas inhabited by Indiana rare species

TABLE 3-3

SUMMARY OF ACTION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
FEDERAL				
Clean Air Act (CAA) National Ambient Air Quality Standards (NAAQS)	40 CFR §50 and §53	Relevant and Appropriate	Establishes air quality standards for carbon monoxide, lead, nitrogen oxides, particulate matter, ozone, and sulfur oxides emitted from a major source of emissions.	These pollutants may be generated during groundwater treatment or soil excavation, handling, or treatment activities.
CAA National Emission Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR §61	Relevant and Appropriate	Establishes emission standards for particular air contaminants from specific sources.	Hazardous air pollutants may be discharged during groundwater or soil treatment activities.
Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES)	40 CFR §122	Relevant and Appropriate	NPDES permits are required for any discharge to surface water.	Any alternative that includes discharges to surface water would have to comply with the permit requirements.
RCRA Solid Waste Management Regulations	40 CFR §258	Relevant and Appropriate	Establishes design and operating standards for solid waste (nonhazardous) landfills.	Applicable if nonhazardous soil is stockpiled or disposed on site.
RCRA Identification and Listing of Hazardous Waste	40 CFR §261	Relevant and Appropriate	Regulations that govern the procedures for identifying if a material is a hazardous waste.	Specific materials at the site may be classifiable as a characteristic or listed hazardous waste.
RCRA Standards Applicable to Generators of Hazardous Waste	40 CFR §262	Relevant and Appropriate	Establishes standards for generators of hazardous waste.	Applicable for removed wastes determined to be hazardous.

TABLE 3-3

SUMMARY OF ACTION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
RCRA Standards Applicable to Transporters of Hazardous Waste	40 CFR §263	Relevant and Appropriate	Establishes standards for off-site transportation of hazardous waste.	Applicable for removed wastes determined to be hazardous that are transported off site.
RCRA Standards and Interim Standards for Owners and Operators of Hazardous Waste TSD Facilities	40 CFR §§264 and 265	Relevant and Appropriate	Regulations that govern the treatment, storage, and disposal of hazardous waste.	These regulations would be applicable to waste removed from this site including both on-site and off-site management; however, the reuse of treated soils as backfill would not be subject to the disposal facility standard.
RCRA Land Disposal Restrictions (LDRs)	40 CFR §268	Relevant and Appropriate	Identifies hazardous wastes that are restricted from land disposal and waste analysis requirements.	Treatment or disposal of contaminated soils/wastes and/or treatment residuals may be considered hazardous waste subject to land disposal restrictions.
Department of Transportation (DOT) Rules for Hazardous Materials Transport	49 CFR §107 and §§171 to 179	Relevant and Appropriate	Regulations for the transportation of hazardous materials. Requirements cover packaging, marking, labeling, and transportation methods.	Off-site shipments of any contaminated soil that is classified as a hazardous material from this site would have to comply with these regulations.

TABLE 3-3

SUMMARY OF ACTION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
STATE				
Indiana Environmental Remediation Act (IERA)	IC 13-30-10	Relevant and Appropriate	This rule requires certain environmental remediation plans to specify remediation objectives based on specified factors It directs the Indiana Department of Environmental Management (IDEM) to certify completion of plans and to issue covenants not to sue with respect to completed plans.	Applicable to certain remediation plans.
IDEM Solid Waste Management Board (ISWMB)	329 IAC 3 329 IAC 10 329 IAC 11 329 IAC 12 329 IAC 13	Relevant and Appropriate	Establishes design and operating standards for solid waste (nonhazardous) landfills. Indiana adoption of federal identification and listing of hazardous waste (40 CFR §261), applicable to generators of hazardous wastes (40 CFR §262), applicable to transporters of hazardous wastes (40 CFR §263), and for management of specific hazardous wastes and types of hazardous waste facilities (40 CFR §266 Subpart M). Indiana adoption of federal standards and interim standards applicable to owners and operators of wastes treatment, storage, and disposal facilities (40 CFR §§264 and 265).	Applicable if nonhazardous soil is stockpiled or disposed on site. Specific materials at the site may be classifiable as a characteristic or listed hazardous waste. These regulations could be applicable to waste removed from this site including both on-site and off-site management. These regulations detail storage and transportation requirements for solid waste military munitions as well as emergency responses.

TABLE 3-3

SUMMARY OF ACTION-SPECIFIC ARARs AND TBC CRITERIA
SWMU 9 - PESTICIDE CONTROL/R-150 TANK
NSWC CRANE
CRANE, INDIANA

Requirement	Citation	Status	Synopsis	Comment
Indiana Air Screening Levels (IASLs) and Ambient Air Quality Standards (IAAQS)	325 IAC 1-3-4 326 IAC 1-2-52	IASLs are TBC Criteria. IAAQS are Relevant and Appropriate.	325 IAC establishes IASLs which are non-rule guidelines used to by IDEM to evaluate the ambient impact of hazardous contaminants. Establishes primary and secondary ambient air quality standards for the state to the extent necessary to protect public health and welfare and are in accordance with the provisions of the CAA.	When determining a pollutant's maximum allowable concentration, the toxicity of a compound is measured by its permissible exposure limit (PEL). These pollutants may be generated during groundwater treatment or soil excavation, handling, or treatment activities.
Indiana Water Pollution Control Board (IWPCB)	327 IAC 5-4 327 IAC 15-15	Relevant and Appropriate	NPDES permits are required for any discharge to surface water.	Any alternative that includes discharges to surface water would have to comply with the permit requirements.

TABLE 3-4

SUMMARY OF RECEPTOR-SPECIFIC HUMAN RISKS, ECOLOGICAL RISKS, AND RECOMMENDATIONS
SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Receptor Population	Environmental Media	Overall Carcinogenic Risk (Human)	Overall Hazard Index (Human)	Overall Risk (Ecological)	Critical Pathways & Chemicals of Concern	Recommendations
SWMU 9 (Pesticide Control/R-150 Tank Area)						
Future Construction Workers (Adult)	Soil and Groundwater	1.0E-07	7 5E-01	NA	NA	NFA
Future Maintenance Workers (Adult)	Surface Soil	6 6E-08	2.6E-04	NA	NA	NFA
Future Occupation Workers (Adult)	Surface Soil	6 9E-07	2.7E-03	NA	NA	NFA
Future Recreational User (Adult)	Surface Soil, Surface Water, and Sediment	4.0E-06	3.2E-02	NA	NA	NFA
Current/Future Trespassers (Adolescent)	Soil, Surface Water, and Sediment	3.9E-07	1.6E-02	NA	NA	NFA
Future Resident (Adult)	Soil, Surface Water, Sediment, and Groundwater	9.5E-05	1.4E+01	NA	Ingestion of ground water (iron and manganese)	• Proceed to CMS • Collect supplemental hydraulic conductivity data to support CMS
Future Resident (Child)	Soil, Surface Water, Sediment, and Groundwater	9.0E-05	4.7E+01	NA	Ingestion of ground water (cis-1,2-DCE, iron, manganese, and nickel) and dermal contact with ground water (manganese)	• Proceed to CMS • Collect supplemental hydraulic conductivity data to support CMS
Terrestrial Plants and Invertebrates	Surface Soil	NA	NA	Low to negligible	NA	NFA
Mammals and Birds	Surface Soil, Sediment, and Surface Water	NA	NA	Low to negligible	NA	NFA
Aquatic Organisms	Surface Water and Sediment	NA	NA	Low to negligible	NA	NFA

NA = Not applicable.
NFA = No further action.
CMS = Corrective Measures Study
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazene.
DCE-1,2-dichloroethene.

TABLE 3-5

HUMAN HEALTH MEDIA CLEANUP STANDARDS
SMWU 9 - PESTICIDE CONTROL/R-150 TANK AREA
NSWC CRANE
CRANE, INDIANA

Risk Driver	Detection				MCSs
	Minimum (µg/L)	Well Location	Maximum (µg/L)	Well Location	Groundwater (µg/L)
Volatile Organics					
Cis-1,2-dichloroethene	1.7	09GWT0201	130	09GW0401	70[1]
Inorganics					
Iron	136	09GW1001	37,300	09GW0201	11,000
Manganese	34.8	09GWT0101	7,920	09GW0201	775

1 - U.S. EPA Maximum Contaminant Level (MCL).

µg/L — micrograms per liter.
MCSs — Media cleanup standards.
N/A — not applicable.
U.S. EPA — United States Environmental Protection Agency.

4.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

4.1 PRELIMINARY SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

Table 4-1 provides a preliminary screening of corrective measures technologies for groundwater. This preliminary screening is conducted to eliminate those technologies that are clearly not applicable to conditions at SWMU 9.

The preliminary technology screening is based on overall applicability to the medium of concern, COCs, and conditions present at SWMU 9. For SWMU 9, the environmental medium of concern has been identified as groundwater. For SWMU 9, cis-1,2-DCE, iron, manganese, and nickel have been identified as COCs. The purpose of this screening effort is to investigate a reasonable range of available technologies and process options and to eliminate those obviously not applicable to the site. The following table summarizes the technologies retained from the preliminary screening:

General Action	Technology	Process Option
No Action	None	Not Applicable
Limited Action	Institutional Controls	Passive Controls: Land Use Controls (LUCs)
	Monitoring	Groundwater Monitoring
	Passive Treatment	Monitored Natural Attenuation

4.2 DETAILED SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

The technologies retained from the preliminary screening are broadly evaluated in this section. The evaluations are based on criteria of effectiveness, implementability, and relative cost, which are defined as follows:

- Effectiveness - This criterion focuses on the potential effectiveness of process options in protecting human health and the environment and in meeting the CAOs and MCSs. This criterion considers potential impacts to human health and the environment during construction and implementation and how proven and reliable the process is with respect to COCs and site conditions.

- Implementability - Implementability is a measure of both the technical and administrative feasibility of implementing a technology. It provides a means of evaluating the ability of a technology to be adapted to site-specific conditions. Technical feasibility includes consideration of construction and

operational issues, demonstrated performance, and adaptability to site conditions. Administrative feasibility considerations include the ability to obtain any necessary permits or easements or adherence to applicable laws and concerns of other regulatory agencies. General availability of necessary equipment and resources is also evaluated.

- Cost - Cost evaluations allow a relative comparison between similar technologies and play a limited role in technology screening. The cost analysis is based on engineering judgment and each technology is evaluated as to whether costs are low, medium, or high relative to the other options in the same technology type. If there is only one process option, costs are compared to other candidate technologies.

The process options presented in the above table for use at SWMU 9 are evaluated in the following sections.

4.2.1 No Action

No Action consists of maintaining status quo at the site. No Action is considered in the CMS process to provide a baseline for comparison with other corrective measures technologies and their effectiveness in mitigating risks posed by site COCs. Because no remedial actions are taken with this technology, there are no costs associated with No Action. There is also no reduction in risk through exposure control or treatment. No action would not be effective in evaluating contaminant mobility and potential migration off site because no monitoring would be performed.

Effectiveness

No Action would not be effective in meeting the CAOs. Because nothing would prevent groundwater use, unacceptable risk could eventually develop because of exposure to contaminated groundwater. Because no monitoring would be performed, there would be no way to evaluate if natural attenuation processes are occurring. In addition, because no groundwater monitoring would be performed, there would be no warning of potential COC migration.

Implementability

There would be no implementability concerns because No Action would be implemented.

Cost

There would be no costs associated with No Action.

Conclusion

No Action is retained as a baseline for comparison although it would not be effective.

4.2.2 Limited Action

Three technologies were retained from preliminary screening: institutional controls, monitoring, and natural attenuation.

4.2.2.1 Institutional Controls

Institutional controls consist of formulating and implementing passive controls such as LUCs to prohibit groundwater use, control future site development, and provide notification for construction projects that may contact groundwater.

Effectiveness

Institutional controls would allow contaminated groundwater to remain on site and would not meet MCSs. However, institutional controls would be effective in meeting the CAOs by restricting exposure to the contaminated groundwater.

Implementability

Institutional controls would be readily implementable for SWMU 9. LUCs would be prepared and described in the Corrective Measures Design (CMD). The Navy could relatively easily prepare and implement the LUCs.

Cost

Costs of institutional controls would be low.

Conclusion

Institutional controls are retained for the development of corrective measures alternatives.

4.2.2.2 Monitoring

Monitoring includes routine inspection and groundwater monitoring to monitor the plume and as a component of natural attenuation. Site monitoring consists of performing regular inspections to confirm the continued enforcement of institutional controls. Groundwater monitoring consists of collecting and analyzing groundwater samples from monitoring wells located upgradient of, downgradient of, and within the plumes.

Effectiveness

Site monitoring would effectively insure the continued application of necessary institutional controls. Groundwater monitoring would be effective in meeting the CAOs by providing a warning of the occurrence of migration and to evaluate the progress of natural attenuation.

Implementability

Site monitoring would be very simple to implement, especially as long as the Navy retains ownership of the site. Groundwater monitoring has already been performed at SWMU 9, and adequate monitoring wells are already in place. Therefore, a new long-term monitoring program could be readily implemented.

Cost

Capital and operation and maintenance (O&M) costs of monitoring would be low.

Conclusion

Groundwater monitoring is retained for the development of corrective measures alternatives.

4.2.2.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) would consist of monitoring groundwater quality to determine the extent to which indigenous microorganisms and natural biodegradation processes along with other natural attenuation processes would break down VOCs and reduce inorganic compound concentrations over time. Increases in the oxidation-reduction potential (ORP) and dissolve oxygen concentration would also reduce the solubility of iron and manganese. Physical processes such as dispersion, dilution, and sorption will also reduce the concentrations of COCs. For this purpose, samples from selected existing wells would be regularly collected and analyzed for MNA parameters such as ORP, dissolved oxygen

(DO), pH, alkalinity, temperature, conductivity, total organic carbon (TOC), ferrous, dissolved, and total iron, dissolved and total manganese, sulfur compounds (sulfides, sulfates), nitrogen compounds (nitrites, nitrates), orthophosphates, chloride, and metabolic gases (methane, ethane, ethene, carbon dioxide).

Effectiveness

Naturally occurring processes are expected to reduce contaminant concentrations in the aquifer over the long term. The full suite of MNA parameters were not measured during the RFI. The limited existing data from well sampling log sheets from the RI suggests that anaerobic MNA processes are reducing chlorinated VOCs. For example, cis-1,2-DCE, a degradation product of TCE, has been observed in samples from several monitoring wells. In addition, dissolved oxygen concentrations less than 1 mg/L and ORP values that are negative have also been observed in many monitoring wells. These conditions favor the anaerobic biological degradation of chlorinated compounds. However, human health risks due to ingestion of groundwater from the aquifer would not be addressed via treatment and would remain until concentrations are reduced by natural processes.

The results from the RFI were compared to the historic data summarized in the RFI Work Plan (TtNUS, 2000). Only a few chlorinated VOCs were detected in the RFI groundwater samples. The maximum concentrations measured in the RFI samples were compared to the maximum concentrations measured in the historic data. For all of the compounds, the RFI values were significantly less than the historic values, which strongly suggests that natural attenuation is occurring. The comparison of the data is summarized below.

Compound	Max. Conc. during RFI, µg/L (Well Number)	Max. Conc. from Historic Data, µg/L (Well Number, Year)
1,1,1-TCA	26 (09-03)	1,200 (09-WT1, 1983)
1,1-DCE	6.4 (09-03)	47 (09-03, 1988)
cis-1,2-DCE	130 (09-04) [69 (09-03)]	220 (09-03, 1992)
TCE	55 (09-03)	990 (WT3P, 1989)

Groundwater monitoring would provide a means of evaluating the concentrations of contaminants in groundwater and assessing the degradation rate of contaminants. Monitoring of indicator parameters within the aquifer would help to evaluate the effectiveness of MNA in reducing contaminant concentrations.

Implementability

MNA would be easy to implement. Monitoring of groundwater and biodegradation, groundwater use restrictions, and periodic site reviews could readily be performed and the necessary resources are available to provide these services.

Cost

Capital and O&M costs for MNA would be low.

Conclusion

MNA is retained in combination with other process options for the development of remedial alternatives.

4.3 SELECTION OF CORRECTIVE MEASURES TECHNOLOGIES AND PROCESS OPTIONS

The following corrective measures technologies and process options are retained to develop corrective measures alternatives:

- No Action
- Institutional Controls
- Monitoring
- Passive Treatment - MNA

Using these technologies, the following two corrective measures alternatives were developed:

- Alternative 1: No Action
- Alternative 2: Institutional Controls, Monitoring, and MNA

The following sections outline the components of each of the corrective measures alternatives to address the contaminated groundwater at SWMU 9.

4.3.1 Alternative 1: No Action

The No Action alternative maintains the site as is and is retained to provide a baseline for comparison to other alternatives. This alternative would not address the groundwater contamination. Existing

monitoring programs and institutional controls would be discontinued, and the site would be available for unrestricted use.

4.3.2 Alternative 2: Monitored Natural Attenuation, Institutional Controls, and Monitoring

Alternative 2 would consist of three major components: (1) Institutional Controls, (2) Monitoring, and (3) MNA.

Component 1: Institutional Controls

Institutional controls would include the limitation of land use to industrial purposes and the prohibition of aquifer use as a drinking water supply. These controls would eliminate or reduce pathways of exposure to contaminants at the site. As part of the Corrective Measures Design (CMD), the details of the controls would be developed. The controls would be implemented during the corrective measure implementation phase to insure that, prior to any future development at SWMU 9, adequate measures would be taken to minimize adverse human health and environmental effects. In particular, LUCs would prevent future site development for residential purposes.

Use of groundwater would be controlled through LUCs, such as requiring well installation and construction permits to be reviewed by appropriate facility departments, such as public works and environmental control.

Component 2: Monitoring

Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess natural attenuation and downgradient of the leading edge of the plume to evaluate contaminant migration. Monitoring would also include routine inspection of the site to verify that no new supply wells have been installed, and that no activities have taken place that resulted in the exposure to contaminated groundwater.

Sampling and analysis for MNA (described below) would consist of collecting samples from six existing monitoring wells in the vicinity of R-150 (WTP05, WTP06, 09T02, 09-04, 09-03, and 09-12) and analyzing them for VOCs and natural attenuation indicator parameters, such as ORP, DO, pH, alkalinity, temperature, conductivity, TOC, ferrous, dissolved, and total iron, dissolved and total manganese, sulfur compounds (sulfates, sulfides), nitrogen compounds (nitrates, nitrites), orthophosphates, chlorides, and metabolic gases (methane, ethane, ethene, and carbon dioxide). Sampling frequency would be quarterly

for the first year and semi-annual thereafter. Because no modeling has been performed for the groundwater, the duration of monitoring is uncertain.

Monitoring for contaminant migration would consist of collecting samples from six existing monitoring wells in the vicinity of R-150 listed above and analyzing them for VOCs, iron (total), manganese (total), and nickel (total). Monitoring for contaminant migration would also consist of collecting samples from four existing monitoring wells in the vicinity of Buildings 55 and 2189 (09T04, 09T05, 09T01, and 09T02) and analyzing them for iron (total) and manganese (total). Sampling frequency would be quarterly for the first year and semi-annual thereafter. Because no modeling has been performed for the groundwater, the duration of monitoring is uncertain.

Component 3: Monitored Natural Attenuation

MNA would rely on naturally occurring processes within the aquifer to significantly reduce the concentrations of chlorinated VOCs and metals. Microorganisms within the aquifer groundwater would use the contaminants as substrate during growth processes. As a result, the contaminants would be metabolized by the microorganisms into other products. Aquifer conditions would have to be continually monitored to ensure that concentrations are being adequately reduced through natural processes. In addition, their degradation products, which are most often less toxic but can produce other toxic products, such as vinyl chloride, would also require monitoring. As the contaminants move downgradient and as oxygen enters the groundwater through precipitation, the concentrations of iron and manganese would gradually decrease as the ORP increases. Nickel concentrations would gradually decrease by precipitation as a hydroxide and/or sulfide and by co-precipitation and/or sorption with iron and manganese compounds.

Reviews would be performed every five years to evaluate site status, assess the continued adequacy of remedial activities and determine whether further action is necessary. The monitoring component would include the maintenance of the existing wells that are sampled.

TABLE 4-1

PRELIMINARY SCREENING OF GROUND WATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SWMU 9 - PESTICIDE/R-150 TANK AREA CORRECTIVE MEASURES STUDY
NSWC CRANE
CRANE, INDIANA

General Response Action	Remedial Technology	Process options	Description	Screening Comment	Retain ?
No Action	None	Not Applicable	No activities conducted at site to address contamination.	Retain for baseline comparison to other technologies.	Y
Limited Action	Monitoring	Sampling and Analysis	Periodic sampling and analysis of groundwater and other media to track the spread of contamination.	Retain to assess natural attenuation and/or migration of contaminants from site and evaluate remedial actions.	Y
	Institutional Controls	Active Controls: Physical Barriers/ Security Guards	Fencing, markers, and/or warning signs to restrict site access.	Retain – Part of overall remedy.	Y
		Passive Controls: Deed and Land Use Restrictions	Administrative action using property deeds to restrict future site activities and use of groundwater.	Retain to limit human exposure to contaminated groundwater. Part of overall remedy.	Y
	Natural Attenuation	Naturally-Occurring Biodegradation and Dilution	Monitoring the groundwater to assess the contaminant dilution, dispersion, or degradation.	Retain. No sources are present and COC concentrations are very low.	Y
Containment	Vertical Barriers	Slurry Wall	Low-permeability wall formed in a perimeter trench to restrict horizontal migration of groundwater.	Eliminate – Excavation through rock would be difficult and expensive.	N
		Grout Curtain	Pressure injection of grout to form a low-permeability perimeter wall to restrict horizontal migration of groundwater.	Eliminate – Effective grouting sandstone fractures would be expensive.	N
	Vertical Barriers	Sheet Piling	Metal sheet piling driven into the ground to restrict horizontal migration of groundwater.	Eliminate – Rock layer would severely restrict constructibility and the depth of the nearest impervious layer makes this technology impractical.	N
		Hydraulic Barrier	Use of extraction wells to restrict horizontal migration of groundwater.	Eliminate – excessive pumping required. Difficult to predict zone of influence of each well. Treatment step would be needed for extracted water.	N
	Horizontal Barriers	Physical Barrier	Injection of bottom sealing slurry beneath source to minimize vertical migration of groundwater.	Eliminate – existing formation below limestone is impermeable.	N
Removal	Groundwater Extraction	Extraction Wells	Series of conventional pumping wells used to remove contaminated groundwater.	Eliminate – in-situ processes are not favorable for this site. Extraction systems for fractured rock are difficult to evaluate and design.	N
		Collection Trench	A permeable trench used to intercept and collect groundwater.	Eliminate – Rock layer would severely restrict constructability	N

TABLE 4-1

PRELIMINARY SCREENING OF GROUND WATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SWMU 9 - PESTICIDE/R-150 TANK AREA CORRECTIVE MEASURES STUDY
NSWC CRANE
CRANE, INDIANA

General Response Action	Remedial Technology	Process options	Description	Screening Comment	Retain ?
In-situ Treatment	Biological	Aerobic	Enhancement of biodegradation in an aerobic environment by addition of chemical additives.	Eliminate – Biological degradation of chlorinated VOCs is most effective in anaerobic environments. Distribution of additives in fractured rock and slit/clay will be difficult. Metals are not removed by biological processes.	N
		Anaerobic	Enhancement of biodegradation in an anaerobic (oxygen-deficient) environment by addition of chemical additives.	Eliminate – Biological degradation of chlorinated VOCs is most effective in anaerobic environments. However, distribution of enhancement chemicals may not be effective in fractured rock. Metals are not removed by biological processes.	N
	Physical/ Chemical	Air Sparging/ Soil Vapor Extraction	Volatilization and enhancement of biodegradation by supply of air and extraction of vapors.	Eliminate – Technology is not effective in rock and silt/clay formations.	N
		Permeable Reactive Barrier (PRB)	Use of a permeable barrier that allows the passage of groundwater and reacts with the contaminants.	Eliminate – Rock layers would severely restrict constructability.	N
		Fenton's Reagent	Chemical treatment of contaminants through oxidation using a solution of ferrous iron and dilute hydrogen peroxide.	Eliminate – COC concentrations are low and distribution of chemical in fractured rock and slit/clay will be difficult.	N
		Potassium Permanganate	Chemical treatment of contaminants through oxidation using a solution of potassium permanganate.	Eliminate – COC concentrations are low and distribution of chemical in fractured rock and slit/clay will be difficult.	N
Ex-situ Treatment	Physical	Filtration	Separation of suspended solids from water via entrapment in a bed of granular media or membrane.	Eliminate - although option is feasible, extraction has been eliminated.	N
		Reverse Osmosis	Use of high pressure and membranes to separate dissolved materials from water.	Eliminate. Reverse Osmosis is not effective on dissolved organics and can damage the membrane.	N
		Air Stripping	Contact of water with air to remove volatile compounds.	Eliminate - although option is feasible, extraction has been eliminated.	N
		Granular Activated Carbon (GAC) Adsorption	Separation of dissolved contaminants from water via adsorption onto GAC. GAC would be regenerated or disposed of off-site.	Eliminate. Chlorinated VOCs are less effectively sorbed on to GAC, making air stripping preferable. May be needed only if very high effluent limits must be met.	N
		Solvent Extraction	Separation of contaminants from a solution by contact with an immiscible liquid with a higher affinity for the contaminants of concern.	Eliminate - not effective for the removal of low concentrations. Uncertain effectiveness for chlorinated VOCs.	N

TABLE 4-1

PRELIMINARY SCREENING OF GROUND WATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SWMU 9 - PESTICIDE/R-150 TANK AREA CORRECTIVE MEASURES STUDY
NSWC CRANE
CRANE, INDIANA

General Response Action	Remedial Technology	Process options	Description	Screening Comment	Retain ?
Ex-situ Treatment (Continued)	Physical (Continued)	Enhanced Oxidation	Use of oxidizers such as air, ozone, peroxide, chlorine, or permanganate to chemically increase the oxidation state of organic and inorganic compounds.	Eliminate – ineffective for low inorganic concentrations.	N
		Sedimentation	Separation of solids from water via gravity settling.	Eliminate - although option is feasible, extraction has been eliminated.	N
	Chemical	Ion Exchange	Process in which ions, held by electrostatic forces to charged functional groups on the resin surface, are exchanged for ions of similar charge in a water stream.	Eliminate – not typically used in the removal of iron and manganese.	N
		Reduction	Use of reducers such as sulfur dioxide, sulfite compounds, or ferrous iron compounds to decrease the oxidation state of organic compounds.	Eliminate – not applicable to the removal of inorganics.	N
		Chemical Precipitation	Use of reagents to convert soluble constituents into insoluble constituents.	Eliminate – pH adjustment is sufficient for the inorganic COCs.	N
		Coagulation/ Flocculation	Use of chemicals to neutralize surface charges and promote attraction of colloidal particles to facilitate settling.	Eliminate - although option is feasible, extraction has been eliminated.	N
		Neutralization/pH Adjustment	Use of acids or bases to counteract excess pHs.	Eliminate - although option is feasible, extraction has been eliminated.	N
	Biological	Aerobic	Natural degradation of organic contaminants via microorganisms in an aerobic (oxygen) environment.	Delete – Not readily applied to very low concentrations of organics.	N
		Anaerobic	Natural degradation of organic contaminants via microorganisms in an anaerobic-(oxygen-deficient) environment.	Delete – Not readily applied to very low concentrations of organics.	N
		Constructed wetlands	Natural degradation of organics and deposition of inorganics through biological activity in constructed wetlands.	Delete – May be difficult to maintain seasonally. Large area required.	N
Discharge/ Disposal	Surface Discharge	Direct Discharge to surface water	Discharge of treated water.	Eliminate - although option is feasible, extraction has been eliminated.	N
		Indirect Discharge to industrial wastewater / sewage treatment plant (IWTP/STP)	Discharge of collected/treated water to base STP or regional publicly owned treatment works (POTW).	Eliminate – Discharge is likely to be too high for existing sewer line. Uncertain excess capacity in sewer and base STP..	N
		Off-Site Treatment Facility	Treatment and disposal of water at an off-site treatment works.	Eliminate – impractical due to large volume of treated groundwater and no treatment plants are within reasonable distance.	N
	Subsurface Discharge	Reinjection	Use of injection wells, spray irrigation, or infiltration to discharge collected/treated groundwater underground.	Retain – large areas are available for recharge although clayey soils severely limit recharge near the ground surface. Injection wells may be feasible.	N

5.0 EVALUATION OF THE CORRECTIVE MEASURES ALTERNATIVES

This section evaluates the corrective measures alternatives presented in Section 4.3. The alternatives are evaluated using criteria set forth in the Office of Solid Waste and Emergency Response (OSWER) Guidance Document 9902.3-2A, RCRA Corrective Action Plan (U.S. EPA, 1995):

- Protection of human health and the environment
- Attainment of MCSs
- Control of release sources
- Compliance with applicable standards for waste management
- Other factors including:
  - Long-term reliability and effectiveness
  - Reduction in toxicity, mobility, or volume of wastes
  - Short-term effectiveness
  - Implementability
  - Cost
  - State acceptance
  - Public acceptance

State acceptance will be evaluated after the State of Indiana has reviewed and commented on the CMS. Public acceptance will be evaluated after comments on the proposed corrective action have been received from the public.

5.1 ALTERNATIVE 1: NO ACTION

5.1.1 Protection of Human Health and the Environment

Alternative 1 is considered primarily for comparison to the other corrective measures. In the short-term, this alternative would be protective of human health and the environment. However, in the long-term, unacceptable risk could develop from exposure with contaminated groundwater because site access and development would be unrestricted and no controls would be in place to prevent groundwater usage and exposure. Also, because no controls would be in place to restrict use of groundwater and no monitoring would be performed to detect migration of COCs in groundwater, unacceptable risks could also develop from exposure to groundwater.

5.1.2 Attainment of MCSs

Alternative 1 may attain the MCSs through natural attenuation processes over time, but there would be no way to confirm that the remedial goals had been achieved.

5.1.3 Source Control

Alternative 1 would involve no additional source control because no action would be performed at SWMU 9. However, the likely sources of contamination (the UST and contaminated soil) have already been removed. No significant sources at Buildings 2189 and 55 were identified. No significantly high concentrations of COCs were identified in the plumes.

5.1.4 Compliance with Waste Management Standards

There are no actions to be implemented for Alternative 1 and therefore, no waste would be generated.

5.1.5 Other Factors

Long-Term Reliability and Effectiveness

The future potential threat to human health would remain because site access and development would be unrestricted and no controls would prevent groundwater usage. Because no site or groundwater monitoring would be conducted, the reliability and effectiveness of this alternative over the long run would not be known.

This alternative would not achieve CAOs because long-term exposure to contaminated groundwater would not be prevented and there would be no warning of the potential migration of COCs in groundwater.

Reduction in Toxicity, Mobility, and Volume

Alternative 1 would involve no reduction in toxicity, mobility, or volume of COCs.

Short-Term Effectiveness

Alternative 1 would involve no action and, therefore, would not pose any risks to on-site workers during implementation and no short-term environmental impacts would be expected.

Implementability

Because no actions would occur, this alternative would be readily implementable. The technical feasibility criteria, including constructability, operability, and reliability, are not applicable.

Alternative 1 would be implemented immediately and would not meet the CAOs and MCSs.

Cost Analysis

There are no costs associated with the No Action alternative.

5.2 ALTERNATIVE 2 – INSTITUTIONAL CONTROLS, MONITORING, AND MNA

5.2.1 Protection of Human Health and the Environment

Alternative 2 would be protective of human health and the environment in the short and long term. Although COCs would remain in groundwater at concentrations greater than MCSs, controls would be put in place that would be protective of human health and the environment by restricting site development and groundwater use. Site monitoring would be protective by insuring continued application of institutional controls. Groundwater monitoring would be protective by warning of any COC concentrations in groundwater. Five-year reviews would be protective by evaluating whether additional measures are required to protect human health and the environment due to changing site conditions or failure of the remedy to be protective.

5.2.2 Attainment of MCSs

Alternative 2 would eventually attain the MCSs. Biological processes via MNA would convert COCs to ethene. Gradual introduction of oxygen to the groundwater would precipitate soluble iron and manganese. Nickel concentrations would be reduced by dispersion, sorption, and co-precipitation with the iron and manganese.

5.2.3 Source Control

Alternative 2 would involve no additional source control at SWMU 9. However, the likely sources of contamination (the UST and contaminated soil) have already been removed. No significant sources at Buildings 2189 and 55 were identified. No significantly high concentrations of COCs were identified in the plumes.

5.2.4 Compliance with Waste Management Standards

Alternative 2 would not involve any removal or treatment of contaminated groundwater. However, groundwater monitoring could generate some investigation derived waste (e.g., purge water) that would have to be disposed appropriately. The volume of waste generated would be small and waste management regulations would be easily met.

5.2.5 Other Factors

Long-Term Reliability and Effectiveness

Alternative 2 would be effective and reliable in the long-term and achieve the CAOs. Institutional controls would effectively prevent potential future exposure to contaminated groundwater. Site monitoring would effectively insure continued application of institutional controls. Groundwater monitoring would monitor the progress of natural attenuation and would effectively warn of any potential migration of COCs. In the event that the institutional controls and MNA are shown not to be sufficiently effective, another more active remedy would be evaluated and implemented.

Reduction in Toxicity, Mobility, and Volume

Alternative 2 would not reduce toxicity or volume of COCs through active treatment. However, organic compounds would degrade through passive biological processes. The mobility of the iron and manganese would be reduced as they oxidize and precipitate. Nickel would likely precipitate with the iron and manganese.

Short-Term Effectiveness

Alternative 2 would involve administration of institutional controls and monitoring. The short-term human health risks associated with these sampling and inspection would be minimal. Monitoring personnel would undergo site-specific health and safety training and wear appropriate personal protective equipment (PPE). Implementation of this alternative would not result in any threat to the surrounding community or ecological receptors.

Implementability

The technical implementation of Alternative 2 would be very simple. Site and groundwater monitoring would also be easy to perform, and the necessary resources are readily available.

The administrative implementation of Alternative 2 would also be simple because SWMU 9 is located within a government-operated facility where LUCs can be strictly enforced. Restrictions for future land and groundwater use would involve legal assistance and regulatory approval.

Alternative 2 would be implemented within approximately 6 months and would meet CAOs upon implementation. However, Alternative 2 would not initially meet MCSs and would require on-going institutional controls and monitoring for an indeterminate period of time.

Cost Analysis

The following costs are estimated for Alternative 2:

Capital Cost:	**$7,000**
30-Year Net Present Worth (NPW) of O&M Costs:	**$295,000**
30-Year NPW:	**$302,000**

The above costs have been rounded to the nearest $1,000 to reflect the preliminary nature of the estimates. Detailed cost estimates are included in Appendix A.

6.0 COMPARATIVE ANALYSIS AND RECOMMENDATION

The following sections provide a comparative analysis of the two corrective measures alternatives, using the same criteria used to evaluate the alternatives in Section 5.0. This comparative analysis is summarized on Table 6-1.

6.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative 1 would not be sufficiently protective of human health and the environment because it would not prevent potential future exposure to contaminated groundwater or warn of potential migration of COCs in groundwater. Alternative 2 would be protective of human health and the environment because it would prevent potential future exposure to contaminated groundwater and warn of potential migration of COCs in groundwater. Alternative 2 would also be most protective because this alternative would eventually attain the MCSs.

6.2 ATTAINMENT OF MCSs

Alternative 1 might eventually meet MCSs, but there would be no way to confirm this. Alternative 2 would eventually meet MCSs.

6.3 SOURCE CONTROL

The likely sources of contamination (Tank R-150 and the contaminated soil) have already been removed, and there is no evidence of soil COCs migration to groundwater or very high concentrations of COCs in groundwater. Neither alternative would not provide any additional source control, although there is no evidence of any sources remaining at the SWMU.

6.4 COMPLIANCE WITH WASTE MANAGEMENT STANDARDS

Alternative 1 would not generate any waste material. Alternative 2 would not generate any treatment residues and would generate a minimal amount of waste materials associated with groundwater monitoring activities. Permitted off-base disposal facilities would be readily available for the disposal of the waste materials generated by Alternative 2.

6.5 OTHER FACTORS

6.5.1 Long-Term Reliability and Effectiveness

Alternative 1 would not be long-term effective and reliable. There would be no way to measure whether CAOs are being met. Alternative 2 would be long-term effective and reliable and meet the CAOs through continued enforcement of institutional controls and monitoring of COCs and natural attenuation parameters.

6.5.2 Reduction in Toxicity, Mobility, and Volume

Alternative 1 may reduce the toxicity or volume of COCs, but any reductions made would not be measured. Alternative 2 would reduce the volume of organic COCs by natural biological degradation. The gradual increase in the groundwater oxidation-reduction potential and dissolved oxygen will likely reduce the mobility of iron and manganese and possibly precipitate nickel.

6.5.3 Short-Term Effectiveness

Alternative 1 would not result in any short-term risks to human health or the environment. Alternative 2 would result in minimal short-term risks to monitoring personnel. These risks would be addressed and adequately mitigated through health and safety training and the wearing of appropriate PPE.

6.5.4 Implementability

Alternative 1 would be the easiest to implement because no action would be required.

The monitoring and institutional controls components of Alternative 2 would be very easy to implement because SWMU 9 is located within a government-owned facility where such controls are easy to enforce.

Alternative 1 would be implemented immediately, but there would be no certainty as to whether CAOs or MCSs would be met. Alternative 2 would be implemented within approximately 6 months and would meet CAOs upon implementation. However, Alternative 2 would not meet MCSs immediately and would require on-going institutional controls and monitoring for an indeterminate period of time.

6.5.5 Cost

The capital cost of Alternative 2 is $7,000. The 30-year NPW of O&M costs for Alternative 2 is $295,000. The 30-Year NPW of Alternative 2 is $302,000. There are no capital and O&M costs associated with Alternative 1. Detailed costs are provided in Appendix A.

6.5.6 State and Community Acceptance

State acceptance will be evaluated after the State of Indiana has reviewed and commented on the CMS. Public acceptance will be evaluated after comments on the proposed corrective action have been received from the public.

6.6 RECOMMENDED CORRECTIVE MEASURE

Alternative 2 is recommended for use at SWMU 9. If, at any time, it is determined that the institutional controls, monitoring, and MNA are not sufficient to effectively protect human health and the environment, a more active approach would be evaluated and implemented. Alternative 2 would require long-term controls and monitoring, but there would be no immediate threat to human health and the environment.

TABLE 6-1

SUMMARY OF COMPARATIVE ANALYSIS OF CORRECTIVE MEASURES ALTERNATIVES
SWMU 9 CORRECTIVE MEASURES STUDY
NSWC CRANE
CRANE, INDIANA

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Institutional Controls, Monitoring, and MNA
Protection of Human Health and Environment	Would not be protective in the long term. No monitoring would be performed, and there would be no warning of potential migration of COCs in groundwater.	Would be protective in the long term. Sampling would monitor progress of natural attenuation and warn of potential migration of COCs in groundwater.
Attainment of MCSs	Would not attain MCSs.	Would attain MCSs.
Control of Release Sources	Would not add additional source controls, but sources are no longer present.	Would not add additional source controls, but sources are no longer present.
Compliance with Waste Management Standards	Not applicable.	Would comply.
Long-Term Reliability and Effectiveness	Would not be long-term reliable and effective and would not meet CAOs. No controls could lead to exposure to contaminated groundwater. No monitoring to of migration of COCs in groundwater.	Would be long-term reliable and effective and meet CAOs. Sampling would monitor progress of natural attenuation and warn of potential migration of COCs in groundwater.
Reduction of Toxicity, Mobility, or Volume	Would not reduce toxicity or volume.	Would reduce volume of organic compounds through biological activity. Mobility of iron and manganese would be reduced with time as ORP and DO concentrations increased.
Short-Term Effectiveness	Would not result in short-term risks to site workers or adversely impact the surrounding community.	Would result in slight risk to monitoring workers. This risk would be reduced through compliance with site-specific health and safety procedures.
Implementability	Would be simple to implement because no action would occur. Would be implemented immediately and not meet CAOs and MCSs.	Technical implementation would be easy. Resources, materials, and equipment are readily available to perform monitoring. Administrative implementation of institutional controls would be simple because NSWC Crane is a federal facility. Would be implemented and meet CAOs within 6 months, but would not immediately meet MCSs and would require institutional controls and monitoring for an indeterminate period of time.

TABLE 6-1

SUMMARY OF COMPARATIVE ANALYSIS OF CORRECTIVE MEASURES ALTERNATIVES
SWMU 9 CORRECTIVE MEASURES STUDY
NSWC CRANE
CRANE, INDIANA

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Institutional Controls, Monitoring, and MNA
Costs:		
Capital	$ 0	$ 21,000
NPW of O&M	$ 0	$ 409,000 (30-Year)
NPW	$ 0	$ 430,000 (30-Year)

CAOs - Corrective Action Objectives.
COCs - Chemicals of Concern.
DO - dissolved oxygen.
MCSs - Media Cleanup Standard.
NPW - Net Present Worth.
O&M - operation and maintenance.
ORP - oxidation-reduction potential.

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APPENDIX A

ALTERNATE 2 COST ESTIMATE

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: SOUTHDIV - Crane	FILE No:N4267	BY: JWL	PAGE: 1 of 4
SUBJECT: SWMU 9 – Conceptual design assumptions and costs for Alternative 2.		CHECKED BY: VJP	DATE: 12/08/04

Purpose: Provide conceptual design on Alternative for monitored natural attenuation (MNA) for purposes of estimate for CMS.

General Assumptions:

MNA monitoring program.

- First two years are quarterly intervals.
- Next three years are semi-annual.
- Annual monitoring thereafter.

There are three plumes to monitor:

- Building 55
- Building 2189
- R-150 Area

Calculations:

The following wells and analyses will be performed, based on RFI observations. (t/d) means total/dissolved):

Building 55

- 09T04 (downgradient) – Ni(t), Fe(t/d), Mn(t/d) (monitoring)
- 09T05 (upgradient) – Ni(t), Fe(t/d), Mn(t/d) (monitoring)

Building 2189

- 09T02 (downgradient) – Ni(t), Fe(t/d), Mn(t/d) (monitoring)
- 09T01 (upgradient) – Ni(t), Fe (t/d), Mn(t/d) (monitoring)

R-150 Area

- WTP6 (upgradient) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA
- WTP5 (former source) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA
- 09T02 (downgradient) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA
- 09-04 (plume) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA
- 09-12 (downgradient) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA
- 09-03 (plume) - Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA

MNA parameters:
Lab (cost)
Alkalinity $15
TOC $20
Fe (d) $10
Fe (t) $10
Mn (t) $10
Mn (d) $10
S $20
SO4 |
NO2, NO3 |---- $60
PO4 |
Cl |
Methane, ethane, ethene - $65

Total $220, allow for contingency and use: $240

VOC $100

Monitoring for inorganics only (Buildings 55 and 2189):
Ni $10
Fe (d) $10
Fe (t) $10
Mn (t) $10
Mn (d) $10

Total - $50

Field analyses:
ORP
DO
pH
Temperature
Conductivity
Ferrous iron
Sulfide
Carbon dioxide

Other sampling event components:
- Equipment rental – PID, Horiba, water level meter (estimate at $600 per event)
- Labor – 2 people, 10 hrs per day, 4 wells per day
- Travel
- Mob/Demob

Field Labor

10 wells at 4 wells per day = 2.5 days, round to 3 days
3 days x 10 hrs/day x 2 people = 60 hours

Travel – 4 hours each way
2 people x 2 ways x 4 hours each way = 16 hours

Mob/demob – order equipment, ship/ etc = 24 hours

Total labor per event = 100 hours
Cost at $50 per hour = <u>$ 5,000 per event</u>

Reporting Labor – write report, figures, database management, review:
60 hours at $50 per hour = <u>$3,000 per event</u>

<u>Lab costs per event per site</u>:

Building 55 – two wells [Ni(t), Fe(t/d), Mn(t/d)] at $50 per well = $100

Building 2189 – two wells [Ni(t), Fe(t/d), Mn(t/d)] at $50 per well = $100

R-150 Area – six wells [Fe(t/d), Mn(t/d), Ni(t), VOCs, MNA] at $350 ($240 + $10 + $100) per well = $2,100

Duplicates (NA, VOC, Ni) = $240 + $10 + $100 = $350

Blanks (VOC) = $100

Field Blank (Fe(t), Mn(t), Ni(t), VOC) = $10 + $10+ $10 + $100 = $130

Total $2,880 round to <u>$2,900 per event</u>

Travel
- Transportation - $300 per person x 2 = $600
- Per diem (Bloomington, IN) 108 per day x 4 days x 2 people = $864, round to $900
- Vehicles - $300/trip = $300

SUMMARY OF SAMPLING COSTS

Item	Cost per event, $
Laboratory	2,900
Field Equipment	600
Field Labor	5,000
Transportation	600
Per diem	900
Vehicles	300
Report	3,000
Miscellaneous	400
Total	13,700
Round to	$14,000

Sampling Plan preparation – assume a large amount of time for data review and evaluation. For example, there may be other existing wells, but data is not available right now. These wells may suggest that additional wells should be sampled.

Assume 80 hours at $60 per hour = $4,800, round to $5,000.

ALTERNATIVE 2: MONITORED NATURAL ATTENUATION,INSTITUTIONAL CONTROLS, AND MONITORIN
CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
CAPITAL COSTS
NSWC CRANE
CRANE, INDIANA

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor[1]	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT PLANNING											
1 1 Prepare Monitoring Plan	80	hr			$62.50		$0	$0	$5,000	$0	$5,000
1.2 Prepare LUC plan	40	hr			$50 00		$0	$0	$2,000	$0	$2,000
Subtotal							0	$0	7000	$0	$7,000
TOTAL COST											**$7,000**

1 - Unit Labor Costs include General and Administrative (G&A) costs, Overhead costs, and profit.

ALTERNATIVE 2: MONITORED NATURAL ATTENUATION,INSTITUTIONAL CONTROLS, AND MONITORIN
CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
ANNUAL COSTS
NSWC CRANE
CRANE, INDIANA

Item	Item Cost Years 1 & 2 (1)	Item Cost Years 3 - 5 (2)	Item Cost Years 6 -30 (3)	Item Cost Every 5 Years Through 30 Years	Notes
Sampling	$31,200	$15,600	$7,800		Labor, Field Supplies.
Analysis/Water	$11,600	$5,800	$2,900		MNA and monitoring
Report	$12,000	$6,000	$3,000		Document sampling events and results
LUC inspection	$300	$300	$300		Annual LUC inspection
Site Review				$7,000	5-year review
TOTALS	$55,100	$27,700	$14,000	$7,000	

1 - Sampling would occur quarterly for the Years 1 & 2.
2 - Sampling would occur semi-annually for the Years 3 - 5.
3 - Sampling would occur annually for the Years 6 - 30.

ALTERNATIVE 2: MONITORED NATURAL ATTENUATION,INSTITUTIONAL CONTROLS, AND MONITORIN
CMS REPORT FOR SWMU 9 - PESTICIDE CONTROL/R-150 TANK AREA
PRESENT WORTH ANALYSIS
NSWC CRANE
CRANE, INDIANA

Year	Capital Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	$7,000		$7,000	1.000	$7,000
1		$55,100	$55,100	0.935	$51,519
2		$55,100	$55,100	0.873	$48,102
3		$27,700	$27,700	0.816	$22,603
4		$27,700	$27,700	0.763	$21,135
5		$34,700	$34,700	0.713	$24,741
6		$14,000	$14,000	0.666	$9,324
7		$14,000	$14,000	0.623	$8,722
8		$14,000	$14,000	0.582	$8,148
9		$14,000	$14,000	0.544	$7,616
10		$21,000	$21,000	0.508	$10,668
11		$14,000	$14,000	0.475	$6,650
12		$14,000	$14,000	0.444	$6,216
13		$14,000	$14,000	0.415	$5,810
14		$14,000	$14,000	0.388	$5,432
15		$21,000	$21,000	0.362	$7,602
16		$14,000	$14,000	0.339	$4,746
17		$14,000	$14,000	0.317	$4,438
18		$14,000	$14,000	0.296	$4,144
19		$14,000	$14,000	0.277	$3,878
20		$21,000	$21,000	0.258	$5,418
21		$14,000	$14,000	0.242	$3,388
22		$14,000	$14,000	0.226	$3,164
23		$14,000	$14,000	0.211	$2,954
24		$14,000	$14,000	0.197	$2,758
25		$21,000	$21,000	0.184	$3,864
26		$14,000	$14,000	0.172	$2,408
27		$14,000	$14,000	0.161	$2,254
28		$14,000	$14,000	0.150	$2,100
29		$14,000	$14,000	0.141	$1,974
30		$21,000	$21,000	0.131	$2,751
				TOTAL PRESENT WORTH	$301,527