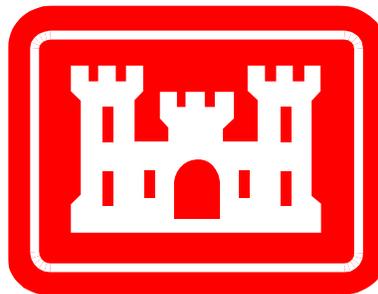


**LINE 1 AND FIRING SITE  
SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT  
IOWA ARMY AMMUNITION PLANT  
MIDDLETOWN, IOWA**

Prepared for:



**U.S. Army Corps of Engineers  
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**DRAFT FINAL**

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## EXECUTIVE SUMMARY

### Purpose

The purpose of this Line 1 and Firing Site Supplemental Remedial Investigation at the Iowa Army Ammunition Plant (IAAAP) was to identify areas of contamination in support of future remedial designs/investigations for removal of contaminated material. This was accomplished by (1) researching production activities and chemical components used at Line 1, (2) using this historical information to determine locations where contaminants may have been released, (3) sampling these locations, and (4) analyzing the resulting data. Further delineation of extent of contamination is to be conducted during the remedial actions/investigations.

The scope is limited to address only chemical, metal and organic sampling. TN&A was not scoped to evaluate for radiological contaminants or to determine radiological areas of concern at Line 1 and Firing Site. Radioactive sampling was only performed to ensure personnel safety as well as the proper handling and disposal of samples. Radioactive sampling of Line 1 and the Firing Site will be scheduled and accomplished by the St. Louis District Corps of Engineers under the FUSRAP program. TN&A was also not scoped to evaluate asbestos as a potential contaminant of concern.

This report for supplemental remedial investigation (RI) for Line 1 and Firing Site at IAAAP was prepared by T N & Associates, Inc. (TN&A) for the U.S. Army Corps of Engineers Omaha District under contract No. DACA45-97-D-0015, Delivery Order No. 0016. This project was conducted over the period 2000 through 2002 and field sampling took place from November 2001 through January 2002.

### Data Quality Objectives

The data quality objectives for this investigation were developed to support the subsequent remedial design/investigations for contaminated areas at Line 1 and Firing Site. The data quality objectives for the investigations at Line 1 and Firing Site are the following:

- Identify targeted sampling locations based on historical data that support the reasonable possibility of releases that could have resulted in soil, sediment, or surface water contamination in excess of pre-defined risk-based action levels. (See the TN&A Work Plan for Line 1 & Firing Site Supplemental RI and Historical Site Assessment, September 2001, for complete historical site assessment information not found in this report.)
- Where appropriate, use field test kits for explosives, both trinitrotoluene (TNT)-related compounds and royal demolition explosive (RDX)/high melting explosive (HMX)-type compounds, to determine the presence of explosives at sufficient concentrations to warrant follow-up sampling and analysis at a laboratory.
- At targeted sampling locations, collect a sufficient number of samples, within budget constraints, and analyze them for target analytes based on past operations to support the identification of areas of concern for explosives, metals and organic contamination.

### Approach to Sampling Design

To prepare the sampling strategy, TN&A divided Line 1 and Firing Site into areas based on physical layout, similarity of past operations, expected types of releases, and possible migration pathways. Based on reports of past operations, TN&A identified the expected types of

contaminants for each area and the types of possible releases (i.e., releases to soil, surface water, or air).

Line 1 was divided into the following areas for soil sampling and analysis:

- Melt buildings
- Machining buildings
- Research and development buildings
- Storage and material inspection buildings
- Component rest houses
- X-ray buildings
- Wood and metal shops
- Former Atomic Energy Commission (AEC) assembly and storage buildings
- Filter buildings
- Cooling towers
- Drainage ways and impoundments

Investigation results are reported in this document grouped in the same way.

The Firing Site was divided into the following areas for sampling analysis:

- FS-1 and FS-2
- FS-3, FS-4, and FS-5
- FS-6, FS-7, and FS-8
- FS-9, FS-10, and FS-11
- FS-12
- FS-14
- FS-15

Investigation results are reported in this document grouped in the same way.

TN&A selected specific sampling locations based on the physical layout, degree of uncertainty in the supporting historical information, reported past practices and operations, and professional judgment.

## **Historical Background for IAAAP Line 1**

IAAAP (originally called the Iowa Ordnance Plant) is an active, government-owned, contractor-operated facility engaged in the loading, assembling, and packaging (LAP) of large-scale ammunition, including projectiles, mortar rounds, mines, and warheads. IAAAP has several LAP operations lines and ammunition storage yards spread across more than 19,000 acres. Constructed in 1941, Line 1 was the first production line in service at IAAAP. Line 1 is approximately 1 mile long, covers 173 acres, and encompasses over 250 buildings and related facilities.

From 1941 until August 1945, production at Line 1 included many types of ammunition, including fixed artillery rounds and bombs, in support of World War II. In 1945, Line 1 was cleaned and placed in extended storage status. In 1947, AEC contracted with Black and Veatch Consultants and Engineers to design facilities at Line 1 for weapon assembly. Existing Line 1 buildings were modified, and new facilities were constructed to support the additional weapons production operations.

In 1947, operations at Line 1 resumed under the authority of AEC. AEC operated Line 1 for the assembly of weapons from 1947 to 1975. According to historical records and information gained during interviews, IAAAP performed all of the operations related to the fabrication and installation of the explosive shells of shaped charges built around the weapon core. IAAAP shipped the completed bombs to storage facilities off site.

## **Historical Background of the Firing Site**

The Firing Site Area was developed for testing explosives and ammunition. The Firing Site Area is approximately 505 acres with 15 structures. Operations at the Firing Site Area centered around the South Firing Site area (FS-6) and the North Firing Site area (FS-12).

In 1947, AEC took over operations of the Firing Site Area. Between 1965 and 1973, a series of specialized tests called “hydro-shots” were conducted exclusively at FS-12. Hydro-shots were tests conducted to observe and test the hydrodynamic performance of shaped explosives used as detonators in ordnances produced by AEC.

- The setup involved assembling the shaped explosives in the form of a hemisphere, roughly the size of half a basketball. Several pounds of explosive were used for each test.
- A ring of DU about 1 or 2 inches (in.) high was placed around the bottom of the explosive hemispherical shell. Records show that the DU used for each test was about 22 kilograms (kg) [48.5 pounds (lb)]. The purpose of the DU ring was to simulate the hydrodynamic conditions in a real (i.e., fully spherical) weapon.
- During the hydro-shot explosion, the DU would reportedly be scattered several hundred feet from the firing point at FS-12.

Hydro-shot testing records at FS-12 show that 701 hydro-shots were performed between December 1965 and December 1973, reportedly dispersing about 4,000 kg (about 8,870 lb) of DU.

AEC turned over control of operations at the Firing Site Area to the Army in July 1975. Before turning the Firing Site Area over to the Army, AEC tested soils at FS-12 for radioactivity and contracted for soil excavation to remove contaminated soil from around the firing point at FS-12.

Since 1975, munitions tested by the Army at the Firing Site Area have included artillery shells, mines, and missiles. DU has recently been found at FS-12.

FS-1 served as an office and administrative building. FS-1 had an X-ray film processing machine used to develop film of test shots performed at the Firing Site Area. . FS-2 was used as an inert storage facility.

Between 1948 and 1952, FS-3, FS-4, and FS-5, three general purpose storage magazines, were constructed. These storage magazines were used to store detonators, booster assemblies and inert materials. There is an environmental chamber in FS-5, which is occasionally used to temporarily store finished products. During AEC operations components for the hydroshots were assembled at FS-5. Depleted uranium (DU) rings used for the tests were stored at FS-5. Currently, FS-3, FS-4 and FS-5 still being used as storage magazines.

FS-7 and FS-8 contained observation bunkers believed to support FS-6 operations.

FS-14 has two test-fire chambers located on the site. Plane wave lens shots and tile shots were performed at FS-14. Little else is known about historical operations at FS-14.

FS-15, located to the west above FS-6 was built in 1986 to support copperhead testing.

Based on the reports of past operations at the Firing Site Area, the types of contaminants expected to be found include conventional explosives, metals, primer materials, and DU used in AEC hydro-shot testing.

### **Remediation Goals (RGs) and Preliminary Remediation Goals (PRGs)**

RGs presented in this report are those values identified in Tables 13 and 14 of the IAAAP Soils Operable Unit # 1 Record of Decision (ROD) prepared by HARZA Engineering Company in August 1998. The RGs are presented on Table 2 part (a) of this report.

PRGs presented in this report were developed in accordance with Section 2.9.2 of the ROD. Section 1.4.1 discusses the development of PRGs as directed by the ROD where specific values were not established. The PRGs are presented on Table 2 part (b) of this report.

### **Contaminants of Concern (COCs) & Contaminants of Potential Concern (COPCs)**

The COCs are those chemicals, metals, or organics, identified in the ROD and found above RGs during this supplemental RI investigation. The COPCs are those chemicals, metals, or organics, not identified in the ROD and found above PRGs during this supplemental RI investigation.

### **Line 1 COCs & COPCs**

The COCs/COPCs reporting above RGs/PRGs included explosives, metals and semivolatile organic compounds (SVOCs). These contaminants are associated with past munitions production and demilitarization at Line 1. Figure 4 shows Line 1 TN&A and JAYCOR locations above RGs and PRGs. Figure 5 shows Line 1 areas of concern. See Table 4 for Line 1 results above RGs/PRGs. The specific types of contaminants found during TN&A sampling at the Line 1 Area are discussed below:

### **Explosives**

Explosives found above RGs at Line 1 are RDX and 2,4,6-TNT. These contaminants were found above RGs in drainage ways and around the doorways of buildings at Line 1. Explosives were also found above RGs in basements of the melt buildings (1-05-1 and 1-05-2), as shown in Figures 4 and 5.

### **Metals**

Metals found above RGs at Line 1 are arsenic, and lead. Barium and silver were found above PRGs. Metals above RGs/PRGs were found in drainage ways and around the doorways of buildings at Line 1, as shown in Figures 4 and 5.

### **SVOCs**

SVOC found above PRGs at Line 1 was indo(1,2,3-cd)pyrene. This contaminate was found above the PRG in drainage ways and around the doorways of buildings of Line 1, as shown in Figures 4 and 5.

### **Firing Site COCs & COPCs**

TN&A sample locations did not report contamination above RGs/PRGs at the Firing Site. JAYCOR reported one location above RG for RDX at FS-14; however, TN&A samples at FS-14 did not confirm RDX above the RG.

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## LIST OF ACRONYMS AND UNITS OF MEASURE

AEC	Atomic Energy Commission
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
COC	contaminant of concern
cpm	counts per minute
DQO	data quality objective
DPT	direct push technology
DU	depleted uranium
EPA	Environmental Protection Agency
FS	firing site
gal	gallon
ft	foot
g	gram
HMX	high-melting explosive
HSDB	Hazardous Substances Data Bank
IAAAP	Iowa Army Ammunition Plant
IDW	investigation derived waste
in.	inch
km	kilometer
L	liter
LAP	loading, assembling, and packing
m	meter
µg/L	microgram per liter
MDL	minimum detection limit
mg	milligram
mL	milliliter
mm	millimeter
MOCA	methylene bis(2-chloroaniline)
QA	quality assurance
QC	quality control
PA	preliminary assessment
PAH	polycyclic aromatic hydrocarbon
PBX	plastic-bonded explosive
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
PRG	preliminary remediation goal
R & D	Research and Development
RCRA	Resource Conservation and Recovery Act
RDX	royal demolition explosive
RG	remediation goal
RI	Remedial Investigation
ROD	Record of Decision

SI	Site Investigation
SVOC	semivolatile organic compound
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TEF	toxicity equivalency factor
TN&A	T N & Associates, Inc.
TNT	trinitrotoluene
TOW	tube-launched, optically tracked, wire-guided
USACE	U.S. Army Corps of Engineers
UPL	upper Poisson limits
UTL	upper tolerance limit
VOC	volatile organic compound

## **1.0 INTRODUCTION**

This report documents findings of the Line 1 and Firing Site Supplemental Remedial Investigation (RI) performed by T N & Associates, Inc. (TN&A) for the U.S. Army Corps of Engineers (USACE)-Omaha District under Contract No. DACA45-97-D-0015, Delivery Order No. 0016.

The primary objective of this supplemental RI was to gather additional information to better determine the nature and extent of chemical, metal, and organic soil contamination in and around the Iowa Army Ammunition Plant (IAAAP) Line 1 and Firing Site in support of future remedial design/investigations. This was accomplished by (1) researching production activities and chemical components used at Line 1, (2) using this historical information to determine locations where contaminants may have been released, (3) sampling these locations, and (4) analyzing the resulting data. The data acquired during this investigation and areas of concern identified will be incorporated (in a separate project) into future remedial designs/investigations to remediate the site.

Further delineation of extent of contamination is to be conducted during the remedial actions/investigations. TN&A was not scoped to evaluate for radiological contaminants or to determine radiological areas of concern at Line 1 and Firing Site. Radiological sampling of Line 1 and the Firing Site will be scheduled and accomplished future activities. TN&A was also not scoped to evaluate asbestos as a potential contaminant of concern. The scope is limited to address only chemical, metal and organic sampling.

There are two soil operable unit Record of Decisions (RODs) that apply to Line 1. The 1997 Interim ROD outlines the interim excavation and temporary stockpiling of contaminated soils. The interim ROD explains that the bulk of contaminated soil volume at Line 1 is due to explosives and metals. The 1998 Final ROD for the soils operational unit # 1, outlines the final treatment and disposal of stockpiled soils. The final ROD was used in the identification of remediation goals and the development of preliminary remediation goals as discussed in Section 1.4.1. The Firing Site was not addressed in either of the RODs.

TN&A performed a 5-month search of the historic records database at IAAAP. During the course of this records search, TN&A personnel interviewed selected former, retired, and active IAAAP personnel and reviewed thousands of microfiche records, engineering drawings, figures, maps, aerial photographs, and documents for information on past operations and possible contaminant releases. Applicable records were assigned a TN&A record number, reviewed, scanned, and copied for inclusion into the TN&A Work Plans for Supplemental RI for Line 1 and Firing Site including Historical Site Assessment (Sept. 2001). These records were placed in a file repository at the TN&A Oak Ridge, Tennessee, office. In addition, all of the drawings, maps, and figures applicable to this assessment were scanned into electronic files so that they can be easily located and accessed.

The historical site assessment information cited above is summarized in this report. For the complete and detailed historical site assessments, see the TN&A Line 1 and Firing Site Work Plans and Historical Site Assessment (Sept. 2001).

In addition to the historical research performed by TN&A, the analytical results from previous environmental investigations were used in developing this report. In particular, TN&A results from the RI performed by JAYCOR (1996) were used as initial field screening data in the

selection of sampling locations. Comparison between TN&A data and JAYCOR data is included where applicable in this report.

## **1.1 Historical Site Summary**

### **1.1.1 Site Locations**

IAAAP occupies approximately 19,015 acres (30 square miles) in Middletown, Iowa (Figure 1). Line 1 is within the IAAAP boundaries in the northeast corner of the plant (Figure 2). Line 1 is approximately 1 mile long, covers 173 acres, and encompasses over 250 buildings and related facilities.

The Firing Site encompasses 505 acres in the western portion the IAAAP boundaries (Figure 3).

### **1.1.2 Summary of Line 1 History**

This section provides a brief summary of the history of Line 1 in a chronological format. For more detailed information on the history of Line 1 see the TN&A Supplemental RI Work Plan and Historical Site Assessment (Sept. 2001).

#### **1.1.2.1 Land Acquisition and Construction of Line 1**

The main body of Line 1 buildings present today were constructed before September 1941. Prior to construction, the area was private farmland. In November 1940, an area of approximately 19,000 acres was acquired by the Office of the Quartermaster General for the construction of IAAAP, of which 137 original acres were used for the Line 1 area.

Construction, which began in January 1941, was performed by A. Guthrie and Construction Co., Inc., and Al Johnson Construction Co. Nearly all of the existing frame structures (private farmhouses, barns, etc.) were removed. Operating buildings were built to be long lasting, with concrete foundations and floors, steel frames and roof trusses, hollow tile walls, and asbestos roofing. [TN&A is aware that many structures at Line 1 have asbestos insulation; however, TN&A is not scoped to evaluate asbestos as a contaminant of concern (COC).] Sewer tiles were constructed and connected to a central sewage treatment plant located south of Line 1. Construction of Line 1 was completed in September 1941, and operations began immediately thereafter.

#### **1.1.2.2 Army Production Begins**

Loading operations were contracted by the Army to Day & Zimmerman and began on Line 1 in September 1941. Materials for ammunition production were shipped to Line 1 by train. These materials were housed in storage buildings and conveyed from the storage buildings to the melt buildings.

Shells produced at Line 1 during this time contained a mixture of trinitrotoluene (TNT) and ammonium nitrate (amatol) explosive. The amatol mixture was prepared by melting TNT and incorporating ammonium nitrate. During the pouring process, a small amount of TNT that tended to crystallize on top of the outside of the shell was removed and collected on the floors. To

prevent accumulation, the floors were steam-cleaned daily. The water from these cleanings was washed outside the doorways into drainage ditches.

Melt Buildings 1-05-01 and 1-05-02 were reportedly the primary source of explosives contamination during this time period. Documented information on the disposal practices during 1941–1947 is limited. However, based on interviews with employees who worked at Line 1 during this time period, the network of man-made drainage ways outside of almost every building was most likely used to convey wastes to Brush Creek.

Production of ammunition was terminated on August 14, 1945. Operations after that date consisted only of completing work in process and renovating rejected ammunition.

Operation by the contractor terminated in January 1946. The Government assumed the operation of long-term storage, surveillance, demilitarization, and reconditioning activities. In 1951 Mason & Hanger Corporation took over operations of IAAAP.

### 1.1.2.3 Atomic Energy Commission Operations (1947–1975)

Atomic Energy Commission (AEC) operations of Line 1 brought construction of new buildings and facilities, weapons and materials, and new potential for environmental contamination.

#### 1.1.2.3.1 AEC Operations (1947–1954)

In 1947, AEC took over operations of the Line 1 facilities. In the same year, AEC contracted Black & Veatch Consultants and Engineers to design the facilities needed in weapon production. During this construction, many of the buildings were renovated and retooled. This construction represents the first phase in the changes implemented by AEC during its occupation of Line 1. Notable changes were made to Buildings 1-04, 1-03, and 1-10. Building 1-08-2 was removed and replaced by Building 1-60 (barium nitrate preparation).

The first item of production after AEC took over operations at Line 1 was baratol (a mixture of barium nitrate and TNT) and cyclitol [a mixture of royal demolition explosives (RDX) and TNT] castings. The core buildings used in baratol production were Buildings 1-60, 1-04 (baratol lab), 1-03 (sample casting preparation and crusher building), 1-10 (baratol machining bay), 1-05-1 and 1-05-2 (melting and casting). Other support buildings for this process were 1-06-01, 1-06-02, and 1-08-01 (TNT storage and preparation buildings); 1-50 (TNT inspection and transfer) and 1-71, 1-72, 1-74, 1-75, and 1-76 (explosives components rest houses). Also, Building 1-73 was used as an X-ray facility. This building was used to X-ray completed components to find flaws and to collect data needed to make improvements.

After many practice runs, baratol casting production started on November 2, 1948. In January 1950, ortho and para nitrotoluene were introduced during the melting process to prevent outer component cracks that sometimes occurred in the castings during room temperature changes.

In the summer of 1951, construction of new processing facilities began to produce two different weapons models at the same time. This represents the second phase of construction made by AEC operations at Line 1. Most of this phase of construction was not completed until 1952 or later.

A new X-ray Building was built (1-100) to replace the smaller inadequate X-ray Building 1-73. X-ray Building 1-100 contained two 1,000,000-volt (v) X-ray machines. The building also contained four machining bays to complete explosives machining operations required prior to X-ray. Contaminated water from the machining operations flowed through aluminum-lined gutters to the Filter Building or Clarifier 1-70 where solids were removed before the water was discharged into Brush Creek.

An additional Component Rest House was built containing eight bays (1-07), a Machining Building with 22 bays (1-40), and an Assembly and Shipping Building with 12 operating bays (1-61). Additional machining bays (six each) were converted in areas of Buildings 1-10 and 1-12.

Wastewater from baratol production was collected in clarifiers. The heavy particulate matter was collected and burned northeast of Line 1 in the West Burn Pad Area. The effluent from the clarifiers was discharged through a system of ditches into an impounding reservoir, which was dumped during periods of heavy rain to dilute the effluent safely and to reduce contamination of downstream water.

In 1953, anthracene was introduced as an anti-cracking agent in Composition B melts. The levels of anthracene added to the melts were not listed in this document. Also, in May 1953, fly ash was added for the first time to remove dissolved TNT from the effluent entering Brush Creek.

In the summer of 1954, reduced schedules caused many buildings to go into layaway status. Two machining buildings (1-10 and 1-12), one melt building (1-05-1), three rest houses (1-74, 1-75, and 1-76), and a filter house (1-70) were some of the buildings put into layaway status during this time.

In October 1954, use of a new industrial solvent, Vythene C (1,1,1-TCA), was used instead of trichloroethylene (TCE) and acetone for cleaning purposes. The gauge maintenance shop located in Building 1-01 was one of the primary users of these cleaning solvents.

#### 1.1.2.3.2 AEC Operations (1954–1975)

Documentation during this period of AEC's history is limited because of to the secretive nature of AEC operations requiring many documents to be classified.

However, AEC continued explosives machining operations in the production of explosives casts for weapons until pressing of plastic explosives into molds replaced the machining operation. A plastics laboratory was established in Building 1-60 in 1962. Also in 1962, the effluent waste system was upgraded to collect waste at its source and transfer it along piping systems to a treatment system. Installation of cooling towers was started in 1962. A limited amount of information exists about AEC operations after 1962.

#### 1.1.2.3.3 Army Operations (1975–Present)

In 1975, AEC turned over operations of Line 1 to the Army, which began production of 155 mm artillery ammunition. Operation of Line 1 was contracted by the army to the still present Mason & Hanger Corporation. The production of 155 mm rounds was later moved to Line 1 from Line 3.

In 1977, Line 1 began production of XM53E2 grenades and tube-launched, optically tracked, wire-guided (TOW) and dragon warheads. A new X-ray unit was installed in Building 1-100 to radiograph HAWK warheads.

During the years 1978 through 1988, munitions production was steady. Weapons produced include TOW, HAWK, Dragon, VIPER, Chaparral, Stinger, Hellfire, Copperhead, Gator, Storm, and XM815 warheads. Waste releases were reportedly regulated and controlled during this period.

During an interview conducted on June 12, 2000, it was mentioned that after Desert Storm, Building 1-85-2 was used by the Army to pull uranium rods out of 120mm artillery shells. A drawing from 1995, entitled “Propellant Dump Fume Ventilation for 105mm & 120mm DU Demilitarization,” illustrates a DU demilitarization bay in Building 1-85-2 as well. As these two sources indicate, the Army has performed demilitarization operations of DU since 1975; however, no manufacturing of DU has been conducted by the Army at this site according to historical research.

The preceding narrative on Line 1 history covers only the background information. More detailed information can be found in the TN&A Line 1 and Firing Site Work Plan and Historical Site Assessment (Sept. 2001).

### **1.1.3 Firing Site Historical Summary**

The Firing Site Area is routinely used for the static testing of ordnance produced at IAAAP. FS-12 has been indefinitely shut down by the IAAAP commander in February 2001 as a result of uranium chunks on the surface. Access has been restricted as a precaution to protect the health of potential trespassers/site visitors.

There are 14 buildings and structures associated with the site. FS-1 served as an office and administrative building. FS-1 had an X-ray film processing machine used to develop film of test shots performed at the Firing Site Area. FS-2 was used as an inert storage facility.

Between 1948 and 1952, FS-3, FS-4, and FS-5, three general purpose storage magazines, were constructed. These storage magazines were used to store detonators, booster assemblies and inert materials. There is an environmental chamber in FS-5, which is occasionally used to temporarily store finished products. During AEC operations components for the hydro-shots were assembled at FS-5. Depleted uranium (DU) rings used for the tests were stored at FS-5. FS-3, FS-4, and FS-5 are currently being used for storage. Currently, FS-3, FS-4 and FS-5 still being used as storage magazines.

FS-7 and FS-8 contained observation bunkers believed to support FS-6 operations.

In 1947, AEC took over operations of the land on which the Firing Site Area would be constructed. Construction of the Firing Site Area began in 1947 and was nearly complete by 1952. Little is known about the building of the Firing Site Area, but documents indicate that the foundations for the sites were wood cribbing supported by substantial concrete. FS-12 was constructed in 1964. Between 1965 and 1973, a series of specialized tests called “hydro-shots” were conducted exclusively at FS-12. Hydro-shots were performed to ensure explosives batch quality and certify performance within specifications for product approval by AEC.

Hydro-shots involved the detonation of shaped explosives in the form of a hemisphere, roughly the size of half a basketball. A ring of depleted uranium (DU) about 1 or 2 in. high was placed around the bottom of the explosive hemispherical shell. Records show that the DU used for each test was about 22 kg (48.5 lb). The purpose of the DU ring was to simulate the hydrodynamic conditions in a real (i.e., fully spherical) weapon.

Documented programs of test firing were instituted at FS-12 including the 57, 61, and 68 programs. All three hydro-shot programs used shells that ranged in weight from 1 to 3 kg (without the DU ring). Records show that 701 hydro-shots were performed at FS-12 between December 1965 and December 1973. This reportedly dispersed about 4,000 kg (8,870 lb) of DU.

AEC ceased all operations at the Firing Site Area in 1975 and returned control of the area to the Army. All real properties were surveyed for radiological condition, including the land. The Firing Site-12 area was the only area where radioactive contamination was found. A series of contamination excavations removed much of the contaminated soil, which was sent to a commercial landfill site at Sheffield, Illinois, for disposal.

Since 1975, munitions tested by the Army at the Firing Site Area have included artillery shells, mines, and missiles. DU has been found at FS-12.

FS-14 and FS-15 were completed in 1972 and 1986, respectively. FS-14 has two test-fire chambers located on the site. Plane wave lens shots and tile shots were performed at FS-14. Little else is known about historical operations at FS-14. FS-15, located to the west above FS-6 was built in 1986 to support copperhead testing.

## **1.2 Site and Regional Setting**

### **1.2.1 Climate**

The IAAAP area has a mean temperature of 11°C. The highest temperature ever recorded was 43.9°C and the coldest was –33°C. The average annual precipitation in the area is 103.2 centimeters (cm). The rainfall is usually well distributed throughout the year and provides ample water for abundant plant growth and the numerous lakes and ponds. The extremes in yearly precipitation range from a high of 122.4 cm recorded in 1947 to a low of 65.5 cm recorded in 1963.

IAAAP is located in a moderate tornado frequency area, as determined by the U.S. Weather Service. According to a Department of Commerce study, the nearby area of Burlington, Iowa, experienced a total of 23 tornadoes over a 12-year period, averaging 1.9 tornadoes per year. The Burlington area is considered to be in an area relatively free from earthquake activity (Installation Assessment of IAAAP, USACE 1980).

### **1.2.2 IAAAP Topography and Surface Drainage**

The topography within IAAAP varies from a flat northern tier to gently undulating terrain with steep slopes forming drainage ways in the southern portion of the installation. The central sector is characterized by flat to rolling terrain dissected by shallow drainage ways. The elevation difference within the installation is approximately 54.9 meters (m), with the average elevation

approximately 182.9 m above mean sea level. Three creeks and their tributaries control the surface drainage. Long Creek drains the western part of the installation, flows into Mathes Lake, and leaves the installation along the southern boundary. Long Creek joins the Skunk River just south of the installation and flows 12.9 kilometers (km) to the Mississippi River. Brush and Spring creeks drain the central and eastern parts, respectively, of the installation. These creeks exit along the southeastern boundary and then flow in a southeasterly direction for approximately 6.4 km before emptying into the Mississippi River (Installation Assessment of IAAAP, USACE 1980).

Five watercourses drain IAAAP (Fig. 2). Little Flint Creek drains a small area in the north of the site. The rest of the installation is drained by, west to east, the Skunk River, Long Creek, Brush Creek, and Spring Creek. Long Creek is a tributary of the Skunk River, which flows to the Mississippi River. Brush and Spring creeks are tributaries of the Mississippi River (HARZA, 1999).

#### 1.2.2.1 Line 1 Topography and Surface Drainage

Line 1 topography is broad, flat to gentle undulating terrain. Drainage ways support almost every building at Line 1. These drainage ways are connected to larger drainage ways that flow into Brush Creek. Brush Creek originates approximately 2000 feet northwest of Line 1 and flows in a southerly direction along the western side of Line 1 to its confluence with Skunk River approximately 6 miles south of Line 1. See figure 5 for identification of drainage pathways and topographical features. Also see JAYCOR figure 6.1-3 in section 6.1 of the JAYCOR RI report for surface drainage patterns.

#### 1.2.2.2 Firing Site Topography and Surface Drainage

The Firing Site Area topography ranges from relatively flat in the south near FS-1 and FS-2 to the small ridge and valley-like terrain caused by the two branches of Long Creek that run across the site in a northwest-to-southeast direction. A relatively flat ridge or terrace exists between the two branches of Brush Creek that widens to the north of the site. FS-12 is located on the southern edge of this ridge. The elevations of the test firing pads in the FS area range from 650 to 675 feet above mean sea level. In general, surface water runoff from the FS area moves eastward toward the two branches of Long Creek. Both branches converge into the main body of Long Creek approximately 3,500 feet northeast of FS-12. Long Creek drains into Mathes Lake approximately 1,000 feet from the northeast perimeter of the Firing Site Area. See figure 9 for identification of drainage pathways and topographical features. Also see Appendix D of the JAYCOR RI report for surface drainage patterns.

### 1.2.3 Geology

#### 1.2.3.1 Regional Geology

IAAAP is located in the Dissected Till Plain section of the Central Lowland Province of the Southern Iowa Drift Plain Region. The site is underlain by a sequence of unconsolidated deposits of Pleistocene age overlying sedimentary bedrock units. The glacial tills consist primarily of silty clay and clayey silt with thin sand seams and lenses and are assigned to the Kellersville Till Member (Illinoisan Age) of the Glasford Formation of southeastern Iowa. The tills extend to depths in excess of 100 ft in portions of the northern half of IAAAP but are thin or absent locally in deeper stream valleys in the south, around Mathes Lake, and in the northeast (HARZA, 1999).

The bedrock underlying IAAAP consists of a sequence of limestones interbedded with varying thicknesses of shales and sandstones, ranging in age from Cambrian to Mississippian. The uppermost bedrock unit beneath the site is associated with the Mississippian Osage Series of southeastern Iowa, composed predominantly of cherty limestones interstratified with minor amounts of shale. The Osage Series is divided into three members: the Warsaw Formation, Keokuk Limestone, and Burlington Limestone. The Warsaw Formation consists primarily of blue-gray calcareous shales, fragmental, fossiliferous, dolomitic limestone, and calcarenites (HARZA, 1999). For a discussion of the hydrologic units and geology identified during well installation see Section 5.1.2.1 and table 5-1 of the JAYCOR RI.

#### 1.2.3.2 Line 1 Site Geology

The geology specific to Line 1 and Firing Site is essentially the same as that of the IAAAP installation. Line 1 geology consists of glacial tills overlain by loess material. The depth of the loess material is approximately 3 to 15 ft. The Kellersville Till is at least 35 ft thick. This till is subdivided into a supraglacial and a subglacial (or basal till) facies. The basal till unit can be observed at the subsurface of Line 1. It is described as silty clay, gray to yellowish brown in color, with trace to little sand (See Appendix C for TN&A Line 1 Geologic Logs). The lithic material that underlies the glacial till follows that of the regional geology.

#### 1.2.3.3 Firing Site Geology

The Firing Site is immediately underlain by miscellaneous fill material consisting of silty clay and debris and by deposits of loess non-stratified silts and clays. Underlying the loess is a glacial till consisting of clay, silt, and sand with interbedded silty-sand seams. The Kellersville Till member of the Glasford Formation is the uppermost unit in the area. The till unit is approximately 14.5 ft thick near Long Creek and 34.5 feet thick in the upland areas. The contact of the glacial overburden with the bedrock is distinctive and often contains a basal silty sand and calcareous till with gravel. The lithic material that underlies the glacial till follows that of the regional geology, (See Appendix C for TN&A Firing Site Geologic Logs).

## 1.2.4 Hydrogeology

### 1.2.4.1 Regional Hydrogeology

In Des Moines County, Iowa, there are four principal aquifers: the glacial drift aquifer and the three bedrock aquifers of the Mississippian, Devonian, and Cambro-Ordovician units. The uppermost aquifer is a discontinuous surficial aquifer composed of unconsolidated loess and glacial till, with thin fluvial deposits of Pleistocene age in the streambeds. These occupy the upland till terrace and are predominantly clayey glacial tills that exhibit low hydraulic conductivities and yield only small quantities of groundwater to wells. Depth to groundwater in the drift is generally less than 10 ft, and shallow groundwater flow parallels surface topography. Groundwater discharges to the more deeply incised surface drainages (e.g., streams) with additional discharge downward to deeper drift sections and the bedrock aquifer. However, low permeability in the drift restricts downward flow. Recharge to the drift aquifer is slow and is derived from infiltration of precipitation and possibly inflow from adjacent areas.

Information on hydrogeological conditions in the bedrock aquifer underlying the drift is sparse. Generally, groundwater in the limestones would be contained primarily within open bedding planes and joints. Therefore, the occurrence and orientation of these features would control groundwater flow, in part. Also, it is common in the upper Midwest for much of the groundwater in these bedrock units to be found in the more fractured and weathered upper sequence, just under the drift. Where this is the case, the lower drift and upper bedrock aquifers may comprise a single hydraulic system. Sitewide, available groundwater levels suggest that overall flow direction in the bedrock is to the south and east toward the Skunk and Mississippi rivers (HARZA, 1999).

### 1.2.4.2 Line 1 Hydrogeology

There are primarily two types of aquifers present at Line 1: drift aquifers and bedrock aquifers. The drift aquifer consists of shallow, relatively confined sandy silt/silty sand deposits in the floodplain and adjacent till terraces of Brush Creek. The direction of groundwater flow in the drift aquifer at Line 1 is generally convergent toward Brush Creek from the eastern terrace and uplands.

The Kellersville Till is distinguished from pre-Illinoian till by its high illite and dolomite content that tends to harden or indurate the till. The mineral matter fills the interstitial spaces, reducing porosity. Soil borings at Line 1 indicated that the percentage of sand increases above a denser clay-rich perching unit creating a more permeable zone within the lesser permeable till. Typically in the near-surface units with low vertical conductivity, groundwater flow is nearly horizontal in the tills and moves horizontally to the higher hydraulic conductivity zones.

Dilute hydrochloric acid testing and visual classification of continuous soil sampling of bore holes revealed that the till above the sandy water-bearing zone is reworked, leached, and oxidized with organics. The lower perching unit is mostly an unleached reduced till of uniform texture. The depth of the water-bearing sandy seam ranges from 2 to 32 ft in depth, with the deeper portion of the seam located in the upper terrace area. The sandy zone slopes toward Brush Creek where groundwater is discharged into the creek system. For an evaluation of groundwater at Line 1 & Firing Site please see the URS Draft Final Fall 2000 and Spring 2001 Groundwater monitoring report.

### 1.2.4.3 Firing Site Hydrogeology

The drift aquifer intercepted at the Firing Site consists of shallow, relatively confined sandy silt/silty sand deposits in the floodplain and adjacent till terraces of Long Creek. The direction of groundwater flow at the Firing Site is generally convergent toward the western and northern branches of Long Creek from the uplands. Two interbedded, water-bearing, sandy silt zones were encountered during the JAYCOR RI. The uppermost sand zone was encountered at 6.0 to 8.5 ft below ground surface (bgs) and averages 3 ft in thickness. The lower silty sand zone is located near the bedrock interface at 14.5 to 34.0 feet bgs in the uplands area.

The Kellersville Till is distinguished from pre-Illinoian till by its high illite and dolomite content that tends to harden or indurate the till. The mineral matter fills the interstitial spaces reducing porosity. Soil borings at the Firing Site indicate the hardened basal till acts as a perching unit. The interbedded silty sand zones that occur above the basal till create permeable zones which allow water transmission. These two lithologies slope from the terrace and uplands toward Long Creek where shallow groundwater is discharged into the creek system. For an evaluation of groundwater at Line 1 & Firing Site please see the URS Draft Final Fall 2000 and Spring 2001 Groundwater monitoring report.

## 1.3 IAAAP Previous Environmental Investigations

Environmental investigations of the installation began in 1980 when an installation assessment was performed. The U.S. Environmental Protection Agency (EPA) Region 7 carried out an assessment of IAAAP in 1987 under the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments and concluded that contaminant releases had occurred. A Federal Facility Agreement was signed in 1988 between EPA and the U.S. Army. EPA proposed IAAAP for the National Priorities List, and the site was added to the list in 1990. In 1991 a Preliminary Assessment (PA) was completed. Based on the PA/Site Investigation (SI), EPA and the Department of Defense entered into an interagency agreement that the site was to be cleaned up under the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA). The agreement allows RCRA and CERCLA activities at the site to be coordinated.

In 1992, RI and feasibility study activities began under the management of the U.S. Army Environmental Center. Results of the RI were reported in the *Revised Draft Final Remedial Investigation/Risk Assessment, Iowa Army Ammunition Plant, Middletown, Iowa* (JAYCOR 1996). The RI included the results of the baseline risk assessment performed by ICAIR Life Systems, Inc. See Section 5.0 for a discussion on how the JAYCOR RI was used in this investigation.

Beginning in 1994, USACE – Omaha was tasked with remedial design and remedial actions based on the U.S. Army Environmental Center RI data. In the fall of 1997, the U.S. Army Environmental Center was assigned to an oversight role, and USACE was tasked to complete the environmental remedial actions for soil and groundwater. USACE used HARZA Engineering Company to determine the fate and transport of explosives compounds from soil to groundwater. The HARZA work was reported in the following deliverables:

- Basewide Groundwater Data Gap Work Plan (July 1996)

- Supplemental RI Basewide Groundwater Data Gaps (February 1997) (HARZA 1997). This includes reproducible copies of the RI and historical aerial photographs.
- Ecological Risk Assessment Addendum, Feasibility Study, Proposed Plan and Record of Decision for Basewide Groundwater (March 1997)
- Feasibility Study, Proposed Plan and Record of Decision for the Treatment of the Interim ROD for Operable Unit 1 Soils (December 1997)
- Supplemental Ecological Risk Assessment Addendum, Long-Term Monitoring for FY00 and the Long-Term Monitoring Plan (June 1999) (HARZA 1999)

Based on the RI, a Record of Decision (ROD) for the interim soils for Operable Unit (OU) 1 was signed in September 1998. This ROD, which addresses Line 1, has been previously signed by EPA and USACE.

## 1.4 Contaminants of Concern

### 1.4.1 Remediation Goals and Determining Preliminary Remediation Goals

The ROD contains remediation goal (RG) values (Tables 13 and 14 of the ROD) for 17 contaminants of concern (COCs), including metals, polycyclic aromatic hydrocarbons (PAHs), explosives, and polychlorinated biphenyls (PCBs). Table 2 part (a) in the tables section of this text contains the list 17 COCs and their RG values. Contaminants of potential concern (COPCs) identified during this supplemental remedial investigation, not identified in the ROD, have been developed as preliminary remediation goals (PRGs). Table 2 part (b) in the tables section contains the list of 40 COPCs and their PRG values.

PRGs for the IAAAP Soils Operable Unit (OU) #1 were developed for 40 COPCs using the procedures set forth in Section 2.9.2 of the ROD (HARZA, 1998). The procedures in the ROD are for the development of new RGs (called PRGs in this document) for COCs (called COPCs in this document) not identified in the ROD.

These PRG values have been developed from two sets of values. These two categorical values reflect (1) soil concentrations appropriate to a carcinogenic risk level of 1E-6 or a hazard quotient (HQ) of unity for a reasonably maximum exposed individual in an industrial land use setting, and (2) concentrations of substances that would be protective of groundwater in the event of quantitative leaching from the soil matrix. The lower (more stringent) of each value of cleanup options is nominated as the contaminant-specific PRG at OU #1.

U.S. EPA Region 9 preliminary remediation goals (PRGs) were used for the first category of cleanup options. These are based on direct contact with contaminated soils, with a modeled exposure duration appropriate to persons in the workplace rather than at home.

As specified in the ROD, toxicity characteristic leaching procedure (TCLP) PRGs were developed for the second group of options. Under the (conservative) assumption that each COPC has the potential to be mobilized quantitatively from contaminated soil, the latter values were derived from TCLP limits established under the Resource, Conservation and Recovery Act (RCRA) using the 20X rule. However, since there are no promulgated TCLP limits for many of the COPCs, a hierarchy of other groundwater protection standards was employed as alternative

points-of-departure for calculating the soil-borne TCLP PRGs. In descending order of importance, the hierarchy includes:

- (1) 100 times U.S. EPA National Primary Drinking Water Standards [Maximum Contaminant Levels (MCLs)]
- (2) 100 times a U.S. EPA lifetime Health Advisory (HA)
- (3) for carcinogens, 100 times the groundwater concentration corresponding to an extra lifetime cancer risk (ELCR) of 1E-6 risk level based on residential water usage, and
- (4) for non-carcinogens, 100 times the groundwater concentration corresponding to a hazard quotient (HQ) of unity based on residential water usage.

In practice, U.S. EPA region 9 tap water PRGs were the points-of-departure for options 3 and 4.

Exhibit 1 illustrates the groundwater protection standard selection process within this hierarchy for each COPC.

**Exhibit 1 Selecting Groundwater Protection Standards as Points-of-Departure for Calculating TCLP Preliminary Remediation Goals**

Contaminant	Groundwater Protection Standards				
	TCLP Limits (mg/L)	MCLs (mg/L)	Health Advisory (mg/L)	Region 9 Residential Tap Water PRGs (µg/L)	
				Cancer	Non-Cancer
Barium	100	-		-	-
Boron	ND	ND	0.6	-	-
Mercury	0.2	-	-	-	-
Selenium	1	-	-	-	-
Silver	5	-	-	-	-
Acenaphthene	ND	ND	ND	ND	370
Anthracene	ND	ND	ND	ND	1,800
Benzo(k)fluoranthene	ND	ND	ND	0.92	-
Fluoranthene	ND	ND	ND	ND	1,500
Fluorene	ND	ND	ND	ND	240
Indeno(1,2,3-cd)pyrene	ND	ND	ND	184	-
Naphthalene	ND	ND	20	-	-
Pyrene	ND	ND	ND	180	-
Chrysene	ND	ND	ND	9.2	-
Dibenzofuran	ND	ND	ND	ND	24
Di-n-Butyl phthalate	ND	ND	ND	ND	3,600
1,4-Dichlorobenzene	7.5	-	-	-	-
bis 2(ethylhexyl)phthalate	ND	0.006	-	-	-

Contaminant	Groundwater Protection Standards				
	TCLP Limits (mg/L)	MCLs (mg/L)	Health Advisory (mg/L)	Region 9 Residential Tap Water PRGs (µg/L)	
				Cancer	Non-Cancer
carbazole	ND	ND	ND	3.4	-
1,1,1-Trichloroethane	ND	0.2	-	-	-
1,1-Dichloroethane	ND	ND	ND	ND	810
1,1-Dichloroethylene	0.7	-	-	-	-
1,2,4-Trimethylbenzene	ND	ND	ND	ND	12
1,2-Dichlorobenzene	ND	0.6	-	-	-
1,3,5-Trimethylbenzene	ND	ND	ND	ND	12
1,3-Dichlorobenzene	ND	ND	0.6	-	-
2-Butanone	200	-	-	-	-
Acetone	ND	ND	ND	ND	610
Benzene	0.5	-	-	-	-
Carbon disulfide	ND	ND	ND	ND	1,000
Chlorobenzene	100	-	-	-	-
Chloroform	6	-	-	-	-
Isopropylbenzene	ND	ND	ND	ND	660
Methylene chloride	ND	ND	ND	4.3	-
N-Butylbenzene	ND	ND	ND	ND	61
N-Propylbenzene	ND	ND	ND	ND	61
sec-Butylbenzene	ND	ND	ND	ND	61
Tetrachloroethylene	0.7	-	-	-	-
Toluene	ND	1	-	-	-
Trichloroethylene	0.5	-	-	-	-

- = Not applicable

Using barium to illustrate the approach for setting soil concentrations protective of groundwater, the TCLP limit of 100 mg/L for the element was used to derive a cleanup option of 2000 mg/kg by applying the 20x rule. As indicated in Table 2, since this concentration is lower than the U.S. EPA region 9 industrial soil PRG for direct contact (100,000 mg/kg), the 2000 mg/kg value was chosen as the PRG (at IAAAP) for this substance.

Isopropyl benzene as an example of a substance for which there is neither TCLP limit, maximum contaminant level, nor lifetime health advisory for the COPC, the 20x rule was applied to 100 times the U.S. EPA region 9 PRG for residential tap water of 660 µg/L (non-cancer effects) resulting in a groundwater protection cleanup option of 1.32E+6 µg/kg. Since this value is greater than the U.S. EPA Region 9 PRG for industrial soil of 520,000 µg/kg, the latter (lower) value was chosen as the PRG for this compound.

Table 2 lists the designated PRGs for the major contaminants (metals, explosives and PAHs) that are set forth in the ROD, tabulates cleanup options under each exposure scenario for the other COPCs, and illustrates the process by which each PRG was derived.

#### **1.4.2 Line 1 COCs and COPCs**

The COCs are those chemicals, metals, or organics, identified in the ROD and found above RGs during this supplemental RI investigation. The COPCs are those chemicals, metals, or organics, not identified in the ROD and found above PRGs during this supplemental RI investigation. These COCs/COPCs reporting above RGs/PRGs included explosives, metals and semivolatile organic compounds (SVOCs). These contaminants are associated with past munitions production and demilitarization at Line 1. Figure 4 shows Line 1 TN&A and JAYCOR locations above RGs and PRGs. Figure 5 shows Line 1 areas of concern. The specific types of contaminants found during TN&A sampling at the Line 1 Area are discussed below:

##### **Explosives**

Explosives found above RGs at Line 1 are RDX and 2,4,6-TNT. These contaminants were found above RGs in drainage ways and around the doorways of buildings at Line 1. Explosives were also found above RGs in basements of the melt buildings (1-05-1 and 1-05-2), as shown in Figures 4 and 5.

##### **Metals**

Metals found above RGs at Line 1 are arsenic, and lead. Barium and silver were found above PRGs. Metals above RGs/PRGs were found in drainage ways and around the doorways of buildings at Line 1, as shown in Figures 4 and 5.

##### **SVOCs**

SVOC found above PRGs at Line 1 was indo(1,2,3-cd)pyrene. This contaminate was found above PRG in drainage ways and around the doorways of buildings of Line 1, as shown in Figures 4 and 5.

#### **1.4.3 Firing Site Contaminants of Concern**

TN&A sample locations did not report contamination above RGs/PRGs at the Firing Site. JAYCOR reported one location above RGs for RDX at FS-14; however, TN&A samples at FS-14 did not confirm RDX above the RG.

## 2.0 SOIL INVESTIGATION FIELD ACTIVITIES

### 2.1 Data Quality Objectives

The data quality objectives for this investigation were developed to support the subsequent remedial design/investigations for contaminated areas at Line 1 and Firing Site. The data quality objectives for the investigations at Line 1 and Firing Site are the following:

- Identify targeted sampling locations based on historical data that support the reasonable possibility of releases that could have resulted in soil, sediment, or surface water contamination in excess of pre-defined risk-based action levels. (See the TN&A Work Plan for Line 1 & Firing Site Supplemental RI and Historical Site Assessment, September 2001, for complete historical site assessment information not found in this report.)
- Where appropriate, use field test kits for explosives, both trinitrotoluene (TNT)-related compounds and royal demolition explosive (RDX)/high melting explosive (HMX)-type compounds, to determine the presence of explosives at sufficient concentrations to warrant follow-up sampling and analysis at a laboratory.
- At targeted sampling locations, collect a sufficient number of samples, within budget constraints, and analyze them for target analytes based on past operations to support the identification of areas of concern for explosives, metals and organic contamination.

For the purposes of this investigation, DQOs are subdivided into those for screening data and those for definitive data.

#### 2.1.1 Screening DQOs

Screening data were generated in the field using portable or semi-portable equipment and are, by nature, somewhat less reliable than definitive data generated by an accredited laboratory. Screening data do not require the same high levels of quality control (QC) and documentation that are required of definitive data. Screening data should be of sufficient quality to:

- Identify specific COCs at the site
- Identify areas of likely contamination
- Aid in the design and execution of investigative activities

#### 2.1.2 Definitive DQOs

Definitive data are generated at a certified fixed-base or mobile laboratory using client-specified or industry-standard methodologies. Laboratories generating definitive data are required to have a Laboratory Quality Assurance Plan that identifies method-specific QC activities and acceptance criteria as well as overall quality assurance (QA) requirements (e.g., documentation requirements, senior review of analytical data).

The completeness objective for definitive data is 90 percent. Where it is technically feasible, reporting limits for definitive data must be below project action levels (i.e., preliminary objective goals or regulatory limits). Precision and accuracy requirements are established in conjunction

with the laboratory (after it has been selected) and approved by the USACE project team prior to commencement of field work.

Definitive data should be of sufficient quality to:

- Withstand scientific and legal scrutiny
- Support the project decision-making process
- Support remedial design/investigation activities

## **2.2 Field Screening Sample Collection**

Field screening for RDX/TNT in soil samples, collected mainly at the two melt buildings, was performed in addition to the analytical program. A field laboratory was set up to accommodate sample preparation and analysis using approved methods. TN&A field personnel conducted the field screening.

Appendix G, “User’s Guide for Conducting Field Screening of TNT and RDX” (TN&A Line 1 & Firing Site Work Plan and Historical Site Assessment Sept. 2001), prepared by the manufacturer of the field testing kit, was used as guidance for TN&A field personnel performing field screening.

## **2.3 Subsurface Soil Sampling**

This section describes the field methods that were used to collect soil samples by direct push technology (DPT) or hand augering. TN&A drilling logs are presented in Appendix C, and TN&A field forms are presented in Appendix D.

### **2.3.1 Direct Push Technology**

TN&A obtained subsurface soil samples from each of the identified accessible sampling locations by using a Geoprobe track-mounted DPT rig. Soil borings were drilled in compliance with local, state, and federal regulations. The soil samples were collected by DTP using a 2-in. stainless steel soil sampling tool lined with precleaned acetate (i.e., plastic) sleeves.

The soil samples are described in geologic logs prepared in accordance with the USACE Geology Scope of Services in Appendix C.

Samples and sampling locations were surveyed for radiological contamination as discussed in Section 2.5. Any excess soil material was returned to the boring. Decontamination of sampling tools between each sample and decontamination of drive rods between each boring was performed.

After completion of drilling activities, the site was restored as close as possible to its original condition.

### **2.3.2 Hand Augering**

In areas inaccessible for DPT, a hand auger was used to collect soil samples. Each hand auger boring was advanced by manually turning a hand auger equipped with 3-in.-diameter cylindrical stainless steel bits until the auger head filled with cuttings. The hand auger was then pulled from the boring and the cuttings placed into a stainless steel mixing bowl, from which samples were obtained and placed in sample containers. VOC samples were collected directly from the obtained soil volume. The hand augering continued until the total sample depth was achieved. Soil borings were logged for lithologic characteristics. Any excess material was returned to the boring.

## 2.4 Sample Location Surveying

Land surveys of the sampling locations were performed by Egger Engineering and Land Surveying, a qualified subcontractor licensed in the State of Iowa, under the supervision of a TN&A representative. All surveys were performed in metric units with NAD83 as the horizontal datum and NAVD88 as the vertical datum. USACE metric benchmarks at IAAAP were used for the survey. The survey data are reported in both metric and English units in Table 9.

## 2.5 Radiological Control Measures

Based on a review of historical operations, it was determined that there was a possibility of encountering surface or subsurface radiological contamination at Line 1 and Firing Site. Radiological screening was performed to protect the safety of workers and the environment and to verify that radiologically contaminated samples were not collected. When necessary, sampling locations were relocated a short distance to avoid encountering radioactive materials. Two locations at FS-12 were moved for worker safety. Sample locations TFS12032 and TFS12036 were moved due to soil screening readings 50 percent greater than background.

TN&A was not scoped to evaluate for radiological contaminants or determine areas of concern at Line 1 and Firing Site. Radioactive sampling of Line 1 and Firing Site will be scheduled and accomplished by future investigations.

The primary radiological contaminant of concern for radiological screening is depleted uranium (DU), which emits alpha and beta particles and gamma rays. Alpha particles, the primary radiation type produced by DU, are blocked by skin and are not harmful outside the body; beta particles are blocked by boots and clothing. Gamma rays are a form of highly penetrating energy, but the amount of gamma radiation emitted by DU is very low. TN&A source check field forms are located in Appendix D.

### 2.5.1 Radiological Survey Guidance

TN&A standard operation procedure for radiological surveying (Appendix E of TN&A Line 1 & Firing Site Work Plan and Historical Site Assessment, 2001) was followed. This procedure established guidance for the proper use of radiation detectors, as well as administrative controls put in place to protect workers and the environment. A Ludlum beta and gamma detector and pancake probing device were used by the TN&A field sampling team to screen radiological backgrounds.

During soil sampling, an action limit of 1.5 times background was established. According to this limit, an action level is exceeded if screening results are 50 percent greater than background. Background for Line 1 and Firing Site were both established at 50 counts per minute (cpm). If a screening level reading was above 75 cpm (50 percent background), the action limit was exceeded.

Radiological screening of sampling locations was conducted before any sampling activities. If a sampling location reported screening levels 50 percent above background, the sample was placed back into the boring, the sampling location was moved, and standard operating procedures were followed for personnel and equipment screening. Personnel and equipment screening was also performed when sampling was completed at each major sampling area. TN&A was not scoped

to determine radiological areas of concern at Line 1 and Firing Site or evaluate these areas for radiological contaminants.

## **2.6 Management of Investigation Derived Waste**

The investigation derived wastes (IDW) include decontamination water, disposable acetate sampling sleeves, and personal protective equipment. Sampling of acetate sampling sleeves, decontamination water, or PPE was not required. These materials were properly handled and contained until their removal from the site for final disposition. TN&A personnel coordinated the disposal of IDW on site with CENWO-CD-BA-B (Debra Wallin) at (319) 753-7808 or (319) 753-7843.

A portable polyethylene water container and large plastic bags were used to containerize the IDW generated during the investigation. All materials that were free of contamination and could be reused were recycled where economically feasible.

Waste classified as non-IDW, such as waste paper and general garbage, was collected on an as-needed basis to maintain each site in a clean and orderly manner.

## **2.7 Field Implemented Changes**

TN&A encountered a limited amount of change in site conditions during sampling at Line 1 and Firing Site. Some proposed sample locations were moved during field activities when site conditions warranted (low powerlines next to transformer stations) and when historical wastestream features were identified (i.e. drainage ways, outfalls, former explosives wastes container pads, sump areas etc.)

The Field Sampling Plan (FSP) indicated that samples to be analyzed for PCBs will be taken a 0-1 feet and 2-4 feet. These sampling intervals do not cover the 1-2 foot interval. PCBs will more likely be found in the 1-2 foot interval than the 2-4 foot interval because PCBs attach readily to the soil particles. The sampling intervals for PCBs was changed to 0-1 feet and 1-2 feet.

## 3.0 LABORATORY ANALYTICAL METHODS

### 3.1 Analytical Methods

All laboratory analyses of soil samples and field QC samples were conducted using the appropriate analytical methods from *Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846)*, Third Edition.

Volatile soil samples were collected with minimal headspace in 2-ounce widemouth glass jars with Teflon septa lids. The samples were prepared based on the procedures outlined in Method SW5030 by heated purge of a 5-g aliquot taken from the sample container and placed in 5 mL of water and analyzed by Method SW8260B. Volatile water samples (i.e., equipment rinsate blanks and trip blanks) were prepared by Method SW5030B and analyzed by Method SW8260B.

Semivolatile soil samples were prepared by Method SW3540C prior to analysis by Method SW8270C. Semivolatile water samples (i.e., equipment rinsate blanks) were prepared by Method SW3520C prior to analysis by Method SW8270C.

For selected semivolatile analyses by Method SW8270C, analysis for MOCA [4,4-methylene bis(2-chloroaniline)] was requested using a tentatively identified compound (TIC) search after verifying adequate sensitivity of the method by analysis of a series of calibration standards. The laboratory initially extracted four soil blank spike replicates and analyzed them by method 8270. These were spiked at 50ppm on column, which would reflect a sample concentration of 1700 ug/Kg using the laboratory's normal 30g soil sample aliquot extracted to a final 1mL of sample extract with no % moisture correction in the sample. The average % recovery was 85% when quantitated against a 5 point initial calibration performed for this compound on 11/29/01. Details of the spike study and calibration are included in Appendix E. When a search for or MOCA was requested on the COC, a single point 50ppm MOCA standard was run along with the sample extracts to give an approximate retention time and to demonstrate the ability of the instrument to detect the compound. A normal TIC search was then performed on the samples in addition to a mass chromatogram search for MOCA in the retention time range determined by the single point standard. A narrative comment was included to describe this process, and to indicate if this compound was detected.

Polychlorinated biphenyl (PCB) soil samples were prepared by Method SW3540C, then the sample extracts were further processed by Method SW3665A prior to analysis by Method SW8082. PCB water samples (i.e., equipment rinsate blanks) were prepared by Method SW3520C prior to analysis by Method SW8082.

Pesticide soil samples were prepared by Method SW3540C prior to analysis by Method SW8181A. Pesticide water samples (i.e., equipment rinsate blanks) were prepared by Method SW3520C prior to analysis by Method SW8181A.

Metals soil samples were prepared by Method SW3050B prior to analysis by Method SW6010B for all metals except mercury. Mercury soil samples were prepared and analyzed by Method 7471A. Metals water samples (i.e., equipment rinsate blanks) were prepared by Method SW3005A prior to analysis by Method SW6010B for all metals except mercury. Mercury water samples were prepared and analyzed by Method SW7470A.

### 3.2 Data Review

A three-level data review was performed by the analytical laboratory staff prior to the release of all analytical data. The first level consisted of a 100% data review by two analysts and/or the section supervisor, documented by the signature of the responsible analyst or the section supervisor on the case narrative included with each hardcopy data package. This review was performed against a review checklist, customized for each analytical method. The primary analyst, who generated the raw data, reviewed the data according to the laboratory's guidelines for raw data review and the instrumentation guidelines. The complete and correct raw data and summary forms were then compiled into a report. A second analyst or supervisor then performs another analytical review of the raw data and the summary forms.

The second level review consisted of a report review by a qualified analyst or supervisor (e.g., a data reporting specialist), documented by his/her signature on the case narrative included with each hardcopy data package.

The third level report review was performed by the laboratory project manager, and documented by his signature on the cover letter accompanying each hardcopy data package.

Copies of the hardcopy data packages are presented in Appendix F.

### 3.3 Data Validation

The laboratory analytical data was reviewed by the project team to independently validate the laboratory results. One hundred percent of the laboratory analytical data was validated according to method-specific SOPs and/or EPA's Laboratory Data Validation Functional Guidelines for Organics/Inorganics Analyses (EPA 1994a, 1994b). Laboratory-generated statistical QC limits were used as QC acceptance criteria, if possible, and where EPA QC limits were not available. The procedure for the QA/QC assessment of the data is presented in Section 13 of the QAPP Addendum of the Line 1 and Firing Site work Plan.

Project personnel validated each analytical batch to determine if project data quality objectives were met. During this validation process, the following parameters were reviewed: holding time, sample preservation, surrogate recovery, MS/MSD results, LCS results, method blanks, field QC samples (trip blanks, equipment blanks, source blanks, and field duplicates), laboratory duplicates, instrument performance, initial and continuing calibration, internal standard performance, interference check samples, and serial dilutions. Based on a comparison of the data with established QC limits, the project team applied qualifiers to the data as necessary to further validate a reported result. Data qualifiers and definitions, consistent with method-specific SOPs and/or EPA functional guidelines, were used where appropriate in validation. The initial and continuing response factors are to be  $>0.05$ . Should this requirement not be met, all non-detected results to samples associated with the deficiency are to be "R" qualified. Data qualifiers were attached to the tabulated final analytical data to indicate the data quality relative to intended data use. The qualifiers were attached to the data whenever they appear in hard copy or computerized form to ensure that data users are aware of the quality and limitations of the data. Upon completion of data validation, validation summaries and checklists were placed with the original laboratory report packages in the project file. A list of data qualifiers used for this project is presented in Table 10-1 of the QAPP Addendum for the project. These data qualifiers applied to both organics and inorganics.

Overall quality and usability of this data is good. Due to calibration deficiencies, some of the sample results for Acetone were rejected. Acetone is a common lab contaminant.

Copies of the data validation summaries and checklists for data validation are presented in Appendix G.

## 4.0 STATISTICAL ANALYSIS OF RI BACKGROUND DATA

This section contains information on the reassessment of site-wide background soil data collected during the JAYCOR RI at IAAAP and the establishment of upper tolerance or Poisson limits to screen metals in on-site surface soil. Background results from this analysis are presented in Table 3 of this document.

JAYCOR RI background data were used to evaluate metals sample results against soil background levels. Between 103 and 107 soil samples were collected during 1991, 1992, and 1993 by JAYCOR to characterize the site-wide background levels of naturally occurring substances at IAAAP. Figure 4-9 and Table 4.4.1 of the JAYCOR RI show the locations at which JAYCOR took their background samples. In general, the sampling locations were inside plant boundaries, and in areas to the north and west of Line 1 and the Firing site where soils were less likely to have been impacted by plant activities. Locations designated as background in JAYCOR's expanded background study and other sampling and analysis events were, JAB-02 and 03, JAW-64, and RBK01 through RBK-28. All data are tabulated in Appendix F of the JAYCOR RI report.

TN&A collected metals samples from the 0-1 ft interval. In order to evaluate these data, background levels for this interval needed to be established. JAYCOR collected background samples from 0–0.5 ft, 1–1.5 ft, 1.5–2.0 ft, and 3.0–3.5 ft intervals. TN&A chose to evaluate background data from the intervals 0–0.5 ft and 1–1.5 ft because data from these intervals would best represent the background data for samples collected by TN&A at the 0–1 ft interval.

In reassessing these data for screening of on-site surface soil at IAAAP, all data points were examined to (1) confirm that each reported concentration applied to a soil sample and not to a sample from some other medium, (2) determine which and how many data points were below the minimum detection limit (MDL) for each analyte, and (3) for better representation, include only data points from samples collected from depths between 0–1.5 ft.

Sediment samples were excluded in the data set because they are considered a different medium than residual or loess surface soils being sampled and evaluated by TN&A. This evaluation eliminated seven sediment samples and resulted, overall, in either 59 or 62 data points being available for statistical analysis. However, it was found that all the data points for antimony, cadmium, and silver were below their MDLs. These substances were therefore dropped from the evaluation as "not detected in background." Other analytes with data points below the MDL were thallium and mercury (in each case 59 of 62 non-detects), selenium (40 of 62 non-detects), and beryllium (5 of 62 non-detects).

Except for thallium, mercury, and selenium, all data sets were evaluated for distribution using the Shapiro and Francia adaptation of the Shapiro and Wilk "W" test, as applicable to data sets greater than 50 (Shapiro 1998). The five beryllium non-detects were converted to half the beryllium MDL prior to this analysis. Surface soil data for aluminum, barium, chromium, copper, iron, magnesium, sodium, and vanadium were normally distributed. Data for cobalt, nickel, and zinc were log-normally distributed. Data for arsenic, beryllium, calcium, lead, manganese, and potassium conformed to neither normal nor log-normal distributions and were designated as "other."

As described in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Addendum to Interim Final Guidance* (U.S. EPA 1992), the 95 percent upper tolerance limits

(UTL) of the untransformed data were determined for analytes displaying a normal distribution. The 95 percent UTLs of the log-transformed data were determined for analytes that displayed a log-normal distribution, with subsequent conversion to their e exponents. The maximum value of the selenium data and of those whose distribution was designated as "other" were chosen as non-parametric UTLs (Conover 1980, U.S. EPA 1992). Ninety-five percent Upper Poisson Limits (UPL) were calculated for analytes with greater than 90 percent non-detects (mercury and thallium) (U.S. EPA 1992).

Analytical QA/QC issues are dealt with in Appendix A of JAYCOR's RI report and Section 6 of the accompanying risk assessment (Volume 11 of JAYCOR's RI report). At a minimum, all data were considered suitable for screening level applications. The background screening levels were used to assess the possibility that levels of metals in soils at OU #1 were elevated as a result of past practices at IAAAP. This was achieved by comparing all results for OU-specific inorganic analytes to their 95% UTL or UPL. Substances detected at levels in excess of their background screening values are unlikely to be of the same population as those from which the background data were derived, representing, *a priori*, a likely consequence of anthropogenic activity.

## 5.0 LINE 1 AREA-BY-AREA SAMPLE RESULTS AND CONCLUSIONS

This section presents a historical area-by-area summary and sample results from the TN&A field investigation. To organize sample results, Line 1 was divided into building groups based on their historical operations. The building groups were then further broken down by individual buildings.

In developing sampling rationale as well as reporting sample results, TN&A used the sample results from the 1996 JAYCOR Revised Draft Final Remedial Investigation. A total of 154 soil samples were collected by JAYCOR around Line 1 facilities. JAYCOR used field screening to guide the collection of laboratory samples. TN&A collected additional samples around all JAYCOR sample locations with elevated levels of explosives, metals, VOCs, SVOCs, and PCBs. Because JAYCOR sample locations were not surveyed, TN&A personnel used their best judgment in identifying JAYCOR sampling points and in placing TN&A samples. For the most part, JAYCOR sample locations and TN&A sample locations were used to develop areas of concern. All JAYCOR detectable data for Line 1 are located in Appendix A.

Comparing JAYCOR sample results with the current PRGs reveals that the majority of JAYCOR sample results above PRGs were taken around former sump areas. These sump areas were excavated after the JAYCOR investigation. JAYCOR sample results obtained from the former sumps at Line 1 will not be discussed. However, TN&A results from these areas will be discussed in the following area by area sections. The former sump areas believed to have been sampled by TN&A (no survey data available) appear to have been excavated to criteria in the ROD. For more detailed information on past sump excavations at Line 1, see the TN&A Line 1 and Firing Site Work Plan and Historical Site Assessment (September 2001).

JAYCOR sample locations with results above PRGs are provided in Figure 4 along with TN&A sample locations above PRGs. TN&A samples were collected to evaluate each site as well as confirm JAYCOR results. Areas of concern developed from TN&A sample locations are identified in Figure 5. Figures with JAYCOR field screening locations used to guide the collection of the JAYCOR laboratory locations, shown on TN&A Figure 4, can be found in the JAYCOR RI (1996).

This section is supported by the following tables:

Table 1 Line 1 Site and Firing Site Sample Locations and Collection Information

Table 2 Soil Remediation Goals (RGs) and Preliminary Remediation Goals (PRGs)

Table 3 Development of IAAAP Background Levels from JAYCOR Background Data

Table 4 Line 1 Results Above RGs and PRGs

Table 5 Line 1 Results Above Background

Table 4 was primarily used in the development of this section and the areas of concern for Line 1 (Figure 5).

Due to the large number of sample results at Line 1 (both TN&A and JAYCOR), generalizations have been used in this area-by-area summary, where applicable, for sampling locations. For the most part, only sample results reporting above or close to RGs/PRGs for both the TN&A and JAYCOR investigations are reported in this text.

TN&A replicate samples were sent to a USACE laboratory for QA purposes. USACE replicate data is located in Appendix B. A random 10 percent of the field sampling locations (42 samples) were chosen for replicate analyses. The RPD between the two laboratories' reported results for those samples where both laboratories detected method analytes was calculated.

Results show that the data from both laboratories are comparable (i.e., within expected interlaboratory agreement). The overwhelming majority of the replicate locations had results from the primary laboratory and/or the USACE QA laboratory that were non-detects, with both laboratories in agreement on almost all non-detect results. All three replicate locations sampled for PCBs and the one replicate location sampled for organochlorine pesticides had non-detect results from both laboratories. Only one of the five replicate locations sampled for VOCs had toluene detected by both laboratories. The only other VOC analyte detected, other than low concentrations (i.e. <5 µg/kg) of methylene chloride by the USACE QA laboratory and a similar detection (18 µg/kg) of methylene chloride by the primary laboratory, was tetrachloroethene, detected by the USACE QA laboratory at 3.6 µg/kg and not detected by the primary laboratory. Likewise, the number of explosives and SVOCs detected by both laboratories in replicate samples was very small. There were numerous detections of metals where comparisons could be made between the data from the two laboratories. See Table 10 for replicate data comparisons.

TN&A collected samples to be analyzed for methylene-bio-ortho-chloroaniline (MOCA) in areas where MOCA was reportedly used (1-04, 1-10, 1-12, 1-40, 1-53, 1-60, and 1-61). MOCA is a curing agent used in liquid urethane polymers and epoxy resins. MOCA was not expected to be identified because of its volatile character, and no MOCA was reported in any samples taken during this investigation. This information is included in this section to avoid repetition when presenting sample results below and prevent the incorrect conclusion that MOCA may have been detected in other areas discussed in this section.

## 5.1 Melt Buildings (1-05-1 and 1-05-2)

As part of the first group of buildings constructed on Line 1, Melt Buildings 1-05-1 and 1-05-2 started operations in September 1941. Currently, these buildings are in layaway status. However, historically, the Melt Buildings have released explosives-contaminated wastes to Brush Creek through drainage ways as a result of previous explosives melt pouring operations.

Explosives melts consisted of ammonium nitrate, TNT, boron-based explosives, barium-based explosives, RDX, high-melting explosives (HMX), and plastic-bonded explosives (PBX). Different mixtures of these base explosives and other compounds produced amatol, Composition B, baratol, cyclotol, and boracitol melts, respectively. These melts were used in production of explosive components for shell munitions and weapons.

During Army operations from 1941 to 1947, the melts consisted primarily of amatol (TNT and ammonium nitrate mixture). This mixture was poured into shells through a funnel. During the pouring process, a small amount of TNT that tended to crystallize on top of the outside of the shell was removed. The floors were steam-cleaned daily to prevent accumulation. The water from these cleanings was washed outside of the doorways into open drainage ways.

During AEC operations of Line 1 (1947 to 1975), melts consisted of baratol, boracitol, TNT, Composition B, and/or cyclotol. These melts were used to make explosive casts, often generically called "baratols," as a component in weapons. See TN&A Work Plan and Historical

Site Assessment Section 2.4, “Historical Document Review,” Ref. 187 for AEC operations from 1947 to 1954 for more detailed information.

Explosives effluent from these melts continued to be discharged into drainage ways outside the melt buildings until clarifiers and sumps were later built to temporarily contain and filter out explosives sludge material from the effluent. Clarifiers appear on 1948 engineering drawings outside both the 1-05-1 and 1-05-2 melt buildings.

This system was updated when a contaminated water treatment system was installed throughout Line 1 in 1962. This water treatment system consisted of connected piping from sumps leading to a central point for treatment (see TN&A Work Plan Section 2.4, Ref. 162). This piping was identified and photographed during site walkovers.

Based on site personnel interviews, the concrete sumps sometimes overflowed, spilling the explosives effluent on the ground. These sumps were excavated by OHM Remediation Services in 1995. Findings during this remediation effort identified explosives and metals contamination. See TN&A Work Plan and Historical Site Assessment document review Section 2.4.2.8, “Sump Removal Documentation,” for details. The 1996 JAYCOR RI of Line 1 found that all samples reporting explosives were collected around the doorways, sumps, and drainage ditches. However, all of these samples were taken around the north side of the melt buildings. Doorways, drainage areas, and two clarifiers to the south side have not been sampled.

The existence and general location of two sediment ponds (no longer present) were revealed during personnel interviews. These two sediment ponds were located somewhere between the melt building conveyor system (the covered ramp structures leading from Building 1-50 to both melt buildings). These structures were believed to have been in use prior to 1957. Additional data on the sediment ponds was not found. These features could not be located by historical or topographical markers and therefore were not sampled.

More detailed information about the waste water operations at Line 1 melt buildings could not be located throughout the research of historical documents, drawings, aerial photographs, and interviews. Sampling locations were chosen based on available historical information of past melt building operations and analytical results of the JAYCOR RI.

### **5.1.1 Melt Building 1-05-1 Sample Results and Conclusions**

JAYCOR reported sample results for explosives and metals above RGs near the northwest corner and eastern side of Building 1-05-1. The northwest corner contained a sump and has since been remediated. Two TN&A sample locations (100507 and 100509) in the northwest corner reported no explosives or metals above RGs.

TN&A collected field screening samples for metals and explosives from the dirt floors at three locations inside the Building 1-05-1 basement. A small crawl space entrance to the basement is located on the northwest side of the building. Sample location 100524 reported RDX (55.55 mg/kg) above the RG in the left basement bay. Locations 100522 and 100523 reported RDX and TNT below RGs but above detection limits for the middle and right basement bays.

The extent of subsurface contamination in the melt building basement and surrounding areas is not known. A small pool of pink-colored water suspected to be explosives-contaminated water observed by TN&A personnel in the basement suggests that the explosives could be moving to

the surrounding subsurface areas outside of the building basement. The northwestern portion of Building 1-05-1 has been determined to be an area of concern as shown in Figure 5.

The southern side of melt building 1-05-1 was not previously sampled. TN&A collected samples from four locations around the doorways and drainage ways. Samples showed 2,4,6-TNT and HMX below 1 mg/kg. No sample results above RGs/PRGs were detected.

JAYCOR reported three locations containing metals above RGs on the eastern side of Building 1-05-1. TN&A sample locations 100501 and 100502, located outside of doorways, also on the eastern side of Building 1-05-1 did not contain metals above RGs. Further delineation is needed on the eastern side of the building in front of the railway loading docks to follow up on JAYCOR samples that showed levels above RGs.

### **5.1.2 Melt Building 1-05-2 Sample Results and Conclusions**

JAYCOR reported sample results above RGs around the northwest corner and eastern side of 1-05-2. The northwest corner contained a sump and has since been remediated. Sample location 100515 reported RDX above RG on the northwest side. Sample location 100516, also on the northwest side, reported RDX. The northwest portion of Building 1-05-2 and nearby surrounding areas have been determined to be an area of concern, as shown in Figure 5.

TN&A collected field screening samples for metals and explosives from the dirt floors at three locations inside the Building 1-05-2 basement. A small crawl space entrance to the basement is on the southwest side of the building. Sample locations 100527, 100526 and 100525 reported RDX and TNT above action levels in all three locations, as shown in Figure 4.

The extent of subsurface contamination in the melt building basement and surrounding areas is not known. A pool of red colored water suspected to be explosives-contaminated water observed by TN&A personnel inside this melt building basement suggests that the explosives may be moving hydraulically to the surrounding subsurface areas outside of the building basement. The southwest portion of Building 1-05-2 has been determined to be an area of concern, as shown in Figure 5.

JAYCOR sample locations on the northeastern side of the building were taken at a former sump area. Samples were collected from two locations around this side of the building. Sample location 100518, located on the northern end of 1-05-2, lead above RGs. Additional sampling is recommended to determine the extent of contamination on the north and northeastern sides of Building 1-05-2.

## **5.2 Machining Buildings (1-10, 1-12, and 1-40)**

The machining buildings group was historically the primary producer of explosive-contaminated waste at Line 1. Reportedly, the largest releases of the explosive effluent from Line 1 occurred during AEC operations (1947–1975) as a result of explosive machining. Machining of explosives occurred in Buildings 1-10, 1-40, 1-12, and 1-100. X-ray Building 1-100 was used to machine explosives during the QA process. (For sample results for Building 1-100, see Section 5.2 below.

Machining operations primarily consisted of the machining of an explosive cast that would be designed to fit around the core of a weapon. These explosive casts were originally made with

baratol or boracitol. Other explosive constituents used in these castings were Composition B and TNT. Two of the main solvents used in the cleaning and maintenance of the machining equipment were trichloroethylene (TCE) and acetone. Available historical records do not reveal solvent waste management practices or the quantities of solvents used.

Interviews with former employees revealed that explosive casts were replaced by pressing plastic explosives into a mold. These pressing operations occurred in Building 1-12.

During machining operations, water coolant was used to prevent sparks. Water was also used in washing down floors to remove explosives machining waste. During early AEC operations in these buildings, wastewater may have flowed directly into drainage ditches leading to Brush Creek. Based on former employee interviews, waste from explosives machining operations at Building 1-100 flowed directly into a drainage ditch located outside of the building. Also, one employee remembers wastewater from Building 1-40 being connected via a pipeline directly to the Line 1 Lagoon.

In subsequent years, the wastewater from the coolant, along with wash water from the floors, was sent to a sump located outside the machining buildings. The sumps were connected to clarifiers that removed consolidated matter. Wastewater from the clarifiers was connected to carbon filtration systems via aboveground pipeline. After carbon filtration, the effluent was discharged into drainage ditches. The carbon filtration system for effluent from Buildings 1-10 and 1-12 was located in Filter Building 1-70-2. Building 1-40 had a carbon filtration system located just outside, close to the clarifier. Also in later years, contaminated water from the machining operations in 1-100 flowed through aluminum-lined gutters to Filter Building 1-70.

Sumps from Buildings 1-40 and 1-12 were removed by OHM Remediation Services in 1995. It has been documented through interviews and historical documents that clarifiers and piping leading to a carbon filtration system in Building 1-70-1 were present at Building 1-10, which is identical to Buildings 1-40 and 1-12. This information would suggest that sump(s) would be present at Building 1-10 and would have the same effluent treatment system as the other machining buildings. The Building 1-10 sumps have been removed, as confirmed during TN&A site walkovers. Current information could not be found on when these sumps were removed.

Based on interviews, DU was handled in Machining Buildings 1-40 and 1-12. Employees explained machining was performed on the explosives and DU was occasionally “nicked” unintentionally during this operation. This is confirmed by a 1969 document (see TN&A Work Plan Section 2.4, Ref. 135) that stated that a small amount of DU turnings from machining operations mixed with explosives was disposed of at the burning area, also known as the East Burn Pads.

Locations around the drainage ditches, sumps, and clarifiers of the machining buildings were sampled for explosives, metals, VOCs, and SVOCs. See Figure 4 for sampling locations.

Explosives and metals samples were taken around doorways, drainage ways, and clarifiers of Buildings 1-10, 1-12, 1-40, and 1-100 because of the history of explosive effluent that traveled through these areas as a result of the machining of explosives.

Because of solvent use (TCE and acetone) and the historic washing of floors, VOC and SVOC samples were taken around doorways, drainage ways, and clarifiers of Buildings 1-10, 1-12, 1-40, and 1-100.

### **5.2.1 Building 1-40 Sample Results and Conclusions**

The majority of JAYCOR sample points above RGs/PRGs at Building 1-40 were located around former sumps that have been remediated. TN&A collected soil samples from seven locations at 0-6 ft depths at Building 1-40, and the samples analyzed for explosives and metals. No metals or explosives were reported above action levels.

SVOCs were detected above reporting limits but below action levels around 1-40. No further sampling is suggested around Building 1-40.

### **5.2.2 Building 1-10 Sample Results and Conclusions**

No JAYCOR sample locations around building 1-10 reported sample results above RGs/PRGs. JAYCOR sampled for explosives, metals, VOCs and SVOCs.

TN&A collected samples for explosives and metals from nine locations around Building 1-10. At these nine locations, eight VOCs samples and two SVOC samples were collected.

One TN&A sample location reported RDX above its RG. This sample was taken from the 2–4 ft depth from location 101002. The north end of Building 1-10 contains above ground wastewater piping that leads west from the building to Filter House 1-70. Location 101002 is next to this pipeline at the northwest end of Building 1-10. Additional sampling is recommended to delineate this area of concern, as shown in Figure 5.

### **5.2.3 Building 1-12 Sample Results and Conclusions**

JAYCOR reported three samples above action levels for explosives on the northwest side of Building 1-12. These samples were collected around a sump that has since been removed.

TN&A collected samples for explosives and metals from three locations (101201, 101202 and 101203) on the northwest side of Building 1-12. Two of these locations (101202 and 101203) were sampled in areas around the former sump and next to a waste trough leading out of the north end of the building. This half-pipe trough drained wastewater to the former sump. Location 101203 reported RDX above RG taken from the 1-2 ft depth interval. Location 101203 was taken north of the depressional area where the sump once existed. Locations 101201 and 101202 did not report results above RGs.

Further investigation is recommended in order to delineate the extent of contamination around sample location 101203. The northeast portion of Building 1-12 is an area of concern because of the waste management facilities that existed there and TN&A results above RGs. See Figure 5 for areas of concern.

## **5.3 Research and Development Buildings (1-03, 1-04, 1-53, and 1-60)**

Some of the main research and development (R&D) programs over the years at IAAAP were electrolytic disposal of lead azide, activated carbon regeneration for red-water control, and explosives development involving barium nitrate and TNT. Laboratories for plastics and MOCA were located in Building 1-53.

The R&D buildings, with their AEC names, are 1-03, Explosives Testing Lab; 1-04, Baratol Lab; and 1-60, Barium Nitrate Preparation and Plastics Lab. Building 1-53 was historically a plastics laboratory where MOCA was prepared. In February 1962 a plastics laboratory was added to Building 1-60.

Through interviews, it was determined that MOCA was used at Buildings 1-53, 1-60, and 1-61. Historical air sample results indicate that MOCA was also used in Buildings 1-10, 1-12, 1-40, and 1-61. Documents suggest that MOCA was also used in Building 1-04 (See Section 2.4.2.4 of the TN&A Sept. 2001 Work Plan). Available historical documents do not describe MOCA waste management practices. Possible releases will be determined through the collection of VOC soil samples surrounding these buildings.

It is not known how waste was disposed of in these buildings. Based on interviews with former employees, wastes were often disposed of outside the doorways and in drainage ways. Based on this information, potential explosives and metals contamination exists around Buildings 1-04, 1-03, and 1-60 from explosive casting components. In general, samples were collected in areas around drainage ways and doorways where contaminants would most likely have been released.

Before AEC operations (pre-1947), Building 1-03 was known as an equipment test laboratory. Not much is known about operations of this building during this time period. However, during AEC operations, this building was used in testing sample baratol casts, which were used as components in weapon production. This building also contained a sample cast crusher. Disposal methods for these discarded explosives casts are not known.

During Army operations (1941 to 1947), Building 1-04 contained line offices and was used for general purpose and maintenance. Building lists from this period show that Building 1-04 was used for receiving and storage (1944) and receiving and painting (1946). Early AEC operations (1947 to 1975) of the building include a baratol laboratory that was used for research and development in the production of baratol casts. Specific details about the operations of this laboratory are not known.

Building 1-60 was constructed by AEC in 1951 and used in the preparation of barium nitrate that was used to make baratol. Specific details about the operations in Building 1-60 are not known. However, it is likely that preparatory operations were drying and blending or mixing of the barium nitrate to obtain the proper moisture and consistency.

Building 1-53 was used as a chemical equipment and material facility when it was first constructed in 1941. Operations during this period are not known. During AEC operations, Building 1-53 was a plastics laboratory. Specific operations at this laboratory during AEC operations are also not known. A 1948 engineering drawing shows a pipe leading from Building 1-53, discharging into a ditch west of the building.

Areas around the doorways and drainage ways of Building 1-53 have the potential for explosives, VOCs, SVOCs, and metals contamination. Also, the pipe leading from the building could be a potential location for contamination.

### **5.3.1 Building 1-03 Sample Results and Conclusions**

JAYCOR collected samples for explosives, metals, VOCs, and SVOCs from one location south of Building 1-03. No sample results from this location were above RGs/PRGs.

TN&A collected samples for explosives, metals, VOCs and SVOCs from four locations around Building 1-03. Sample location 100303 located below a loading dock on the eastern side of 1-03 reported metals and VOCs above detection limits.

No additional sampling is recommended for Building 1-03.

### **5.3.2 Building 1-04 Sample Results and Conclusions**

Sample location 100404 reported indeno(1,2,3-CD)pyrene above PRGs at Building 100404. A laboratory glassware stopper was found in the soil collected at this location. Other SVOCs were detected below RGs/PRGs.

Additional sampling is recommended around sample location 100404 to identify any other SVOC contamination that may be present.

### **5.3.3 Building 1-53 Sample Results and Conclusions**

JAYCOR collected samples for explosives, metals, VOCs and SVOCs around Building 1-53. JAYCOR sample results did not detect any parameters above RGs/PRGs.

TN&A collected samples for explosives, metals, VOCs, and SVOCs at three locations. Location 105303 was located in a drainage way west of the building. This drainage way is believed to be the drainage way that a pipe, as seen on historical drawings, was discharging into from Building 1-53. Sample results from this location did not report any parameters above action levels. Sample location 105301 reported VOCs and SVOCs above detection limits. Sample location 105302 reported VOCs above detection limits. TN&A sample locations did not report any contaminants above PRGs around Building 1-53.

No additional sampling is recommended for Building 1-53.

### **5.3.4 Building 1-60 Sample Results and Conclusions**

JAYCOR collected samples for explosives, metals, VOCs, and SVOCs from locations around Building 1-60. JAYCOR samples reported results above PRGs for metals and SVOCs on the eastern and western sides of the building.

TN&A collected samples for explosives, metals, VOCs, and SVOCs from five locations. Metals were reported above action levels for barium and arsenic 106005. Location 106004 reported chromium above background. A cooling tower that once existed east of Building 1-60 could be contributing chromium above background in this area. The 12,000 µg/kg barium concentration at location 106005 is the highest barium level reported during this investigation.

This elevated level of barium can be attributed to historical barium nitrate mixing or blending operations performed by AEC in Building 1-60 as a first-stage process in baratol cast production. This is comparable to what has been found on other production lines, in particular the “back line” of Line 6, where washing out of accumulating explosives during drying and mixing operations resulted in metals contamination of nearby soil. (The above text was taken from historical information collected by TN&A on a separate supplemental investigation of Lines 6, 8, 9 and Deactivation Furnace. For more information, see the Line 6 historical site assessment in the TN&A Phase V Sites work plan.)

Location 106005 also contained ideno(1, 2, 3-CD)pyrene above PRG.

Further investigation is recommended in order to delineate the extent of metals and SVOC contamination around Building 1-60.

## **5.4 Material Storage Buildings/Structures**

Historically, a wide range of materials and chemicals was stored at Line 1. The major groups of materials stored are explosives, radiological materials, and solvents. In most cases, only the general uses of these storage buildings are known. Specifics about the amount of storage, the individual material names, and cleaning practices were not found during historical record research.

For clarity, the narrative for these building groups is divided under the subsection headings below.

### **5.4.1 Explosives Storage Buildings (1-06-1, 1-06-2, 1-08-01, and 1-50)**

With the exception of 1-50 (the Transfer and Inspection Building), these buildings were used almost exclusively to store newly shipped TNT and ammonium nitrate during Army operations in the early to mid 1940s. During AEC operations (1947 to 1975), these buildings reportedly stored raw explosive materials, including TNT. Building 1-50 was used as a central transfer point and was used for inspection before the explosives materials were moved by conveyers to the two melt buildings, 1-05-1 and 1-05-2.

#### **5.4.1.1 Building 1-06-1 Sample Results and Conclusions**

Two JAYCOR sample locations around Building 1-06-1 reported results above action levels. TN&A collected samples from two locations nearby these JAYCOR locations on the eastern and western sides of Building 1-06-1.

A JAYCOR location on the eastern side of Building 1-06-1 reported 2,4,6-TNT above RG. TN&A sample location 100601, located just outside the only eastern doorway, did not report any contaminants above action levels for metals and explosives. TN&A did not collect SVOC samples at this location.

The JAYCOR location on the western side of the building reported naphthalene above PRG. TN&A samples taken from a location next to the loading dock on the western side of Building 1-06-1 reported explosives and metals below action levels.

Additional sampling is proposed to locate the explosives and SVOC contamination reported by JAYCOR in this area. TN&A was unable to confirm JAYCOR locations due to the lack of JAYCOR survey data.

#### **5.4.1.2 Building 1-06-2 Sample Results and Conclusions**

JAYCOR sample locations around Building 1-06-2 did not report any results above action levels. TN&A collected samples from two locations on the eastern and western sides of Building 1-06-2. Sample location 100604 reported chromium above background beside a door on the eastern side of the building.

A combined total of four JAYCOR and TN&A sample locations for explosives, metals, VOCs and SVOCs have been sampled and reported results below action levels at the loading dock on the western side of Building 1-06-2.

No Additional sampling is proposed at Building 1-06-2.

#### 5.4.1.3 Buildings 1-08-1 and 1-08-1A Sample Results and Conclusions

One JAYCOR sample location around Building 1-08-1 reported RDX above RG. TN&A collected samples from three locations around drainage and doorway areas on the western and southern sides of the building. Two of these locations reported explosives above detection limits but no explosives above RGs. The limited amount of explosives found by JAYCOR in this area may have biodegraded. No additional sampling is suggested around this building.

Two JAYCOR locations reported explosives above RGs at an outfall and drainage ditch next to Building 1-08-1A located north of building 1-08-1. TN&A samples collected in the drainage ditch at building 1-08-1A did not report any explosives above RGs.

#### 5.4.1.4 Building 1-50 Sample Results and Conclusions

JAYCOR locations did not report any contamination above action levels around Building 1-50. TN&A collected samples for explosives and metals from three locations around Building 1-50. Two TN&A samples were located outside doorways on the northeast and southeast sides of the building. One TN&A location was on the western side of the building. No explosives or metals above detection limits were reported at any of these three locations.

No additional sampling is suggested around Building 1-50.

### 5.4.2 Solvent Storage Buildings (1-03-1 through 1-03-6)

The solvents TCE and acetone were stored in Buildings 1-03-1, 1-03-2, 1-03-3, 1-03-4, 1-03-5, 1-03-6, and 1-03-7. Available documents do not define specific information regarding the management of solvent wastes, the quantities of solvents, and the types of solvents used at Line 1.

#### 5.4.2.1 Solvent Storage Sample Results and Conclusions

JAYCOR sampled for VOCs and SVOCs around all solvent storage buildings (1-03-1 through 1-03-7). JAYCOR reported SVOCs around Building 1-03-1 above action levels for SVOCs.

TN&A sampled around all solvent storage buildings for VOCs and SVOCs. Most solvent storage buildings were small, averaging approximately 250 ft<sup>2</sup>, and contained only one direct outside entrance. Just outside these doorways there were often a small bermed area. TN&A collected samples inside these bermed areas. Exceptions to the above description were Buildings 1-03-1 and 1-03-7.

Sample locations 100304 and 100301 associated with Building 1-03 (laboratory) were located in a drainage ditch outside the doorway of Building 1-03-7. This drainage ditch supports both buildings 1-03 and 1-03-7. There was no bermed area outside the Building 1-03-7 doorway.

Buildings 1-03-1, 1-03-3, and 1-03-4 reported SVOCs above detection limits. Building 1-03-5 reported TCE above detection limits but well below its PRG. However, no samples at the solvent buildings reported levels above action levels for VOCs and SVOCs.

No further sampling is proposed for the solvent storage buildings.

### **5.4.3 AEC Receiving and Storage Buildings 1-11 and 1-85-2**

Building 1-11 was constructed by AEC in 1957 to be used for shipping and receiving raw materials used in assembling ordnance. Raw materials stored in this building included depleted uranium, tritium bottles, and beryllium-containing components. Materials were brought into the building by train.

Building 1-85-2 was built in the last full year of AEC operations in 1974 during the changeover to Army operations at Line 1. This building was designated as a project assembly shipping and receiving building. Historical drawings indicate that mines may have been assembled in this building. The likelihood of contamination from this building is considered low. No data exist to confirm or deny the presence of contaminants around this building.

In an interview conducted on June 12, 2000, by TN&A [see interview transcripts in TN&A Line 1 and Firing Site Work Plan and Historical Site Assessment (September 2001)], it was mentioned that after Desert Storm, Building 1-85-2 was used by the Army to pull uranium rods out of 120 mm artillery shells. A drawing from 1975, entitled “Propellant Dump Fume Ventillation for 105 mm & 120 mm DU Demil,” illustrates a DU demilitarizing bay in Building 1-85-2 as well. As these two sources indicate, the Army may have performed demilitarization operations of DU in this building since 1975 (the year Army took over operations from AEC). Importantly, according to historical research, no manufacturing of DU has ever been conducted by the Army at IAAAP. Collecting radiological samples was not included in the investigation scope of work.

#### **5.4.3.1 Building 1-11 Sample Results and Conclusions**

JAYCOR collected samples for metals and VOCs from two locations around Building 1-11. Neither location reported samples above action levels. TN&A explosives, metals, and VOCs samples from six locations around doorways and drainage ways did not report any contaminants above action levels. Beryllium was not detected above background in sample results.

Based on TN&A sample results, no additional sampling is suggested outside of Building 1-11.

#### **5.4.4 Building 1-85-2 Sample Results and Conclusions**

JAYCOR did not collect samples around Building 1-85-2.

TN&A collected samples for explosives, metals and VOCs from two locations. One location was located beside the main loading dock. The other sample location was located by a door on the south side of the building. No samples reported parameters above action levels. No elevated detection above background was reported from either location.

No further sampling is proposed for this building.

#### **5.4.5 Fuel Storage Buildings/Structures (1-02, 1-36, 1-152-1, 2, 9, 10, 11, 12, and 13)**

Building 1-02 was used as a powerhouse/heating plant and contained fuel storage tanks in the southern end of the building. Detailed historical building operations are not known. The southern end of this building is in layaway status. The northern end of this building is still active.

Building 1-36 was used to store flammable materials. Materials historically stored in this building are not known.

Fuel storage tanks 1-152-1, 1-152-2, 1-152-9, 1-152-10, 1-152-11, 1-152-12, and 1-152-13 are located on the northern end of Line 1. These fuel tanks have a capacity to store 125,000 gal each and were installed from 1973 to 1976. These fuel tanks contain No.2 fuel oil to be used by the Power Plant Buildings 1-62 and 1-148.

##### **5.4.5.1 Building 1-02 Sample Results and Conclusions**

One JAYCOR sample location on the eastern side of Building 1-02 reported mercury and above its PRG. TN&A collected samples for VOCs and SVOCs at 1–2 ft and 2–4 ft depth intervals from six locations around Building 1-02. Two TN&A samples were located around the JAYCOR location reporting SVOC detections on the eastern side of the building. TN&A sample location 100205 reported chrysene at the 2–4 ft depth interval below PRGs south of Building 1-02. No sample results were above action levels.

Additional sampling is suggested to confirm or deny metal contamination reported by JAYCOR in this area.

##### **5.4.5.2 Building 1-36 Sample Results and Conclusions**

One JAYCOR sample location reported SVOCs and metals above action levels at Building 1-36. JAYCOR identifies this location as being taken directly below the south loading dock. TN&A sample location 103602 was also collected directly below the south loading dock and sampled for metals, VOCs, and SVOCs. No samples collected at this location reported contaminants above RGs/PRGs.

TN&A collected samples from two other locations on the northern and western sides of Building 1-36 for metals, VOCs, and SVOCs. Samples from these areas did not report levels above action levels.

TN&A samples did not report any contaminants close to or above action levels around Building 1-36.

No further sampling is proposed for Building 1-36.

##### **5.4.5.3 Fuel Tank Farm Sample Results and Conclusions**

JAYCOR did not report any samples for VOCs or SVOCs above action levels around the tank farm location. No JAYCOR samples appear to have been taken around tanks 1-152-1 and 1-152-2.

TN&A samples were collected for VOCs and SVOCs from 1–2 ft and 2–4 ft intervals at seven sample locations in areas around all fuel tanks. SVOC sample results from location 115205 (Storage Tank 1-152-9) at the 1–2 ft depth and the 2–4 ft depth reported multiple SVOCs above detection limits. Multiple VOCs were detected above detection limits but below action levels at location 115205. Location 115205 is at the bottom slope below the fuel storage tanks refueling station adjacent to the railroad tracks. This refueling station is supported by multiple fuel lines that allowed refueling of the storage tanks by railcar.

During sampling at 115203, a strong petroleum odor was detected after a color change in the soil lithology at 3.5 ft from a pale yellow brown to grayish-blue. VOCs were detected above detection limits but below action levels.

No TN&A samples reported above RGs/PRGs at the tank farm.

No further sampling is proposed for this area.

#### **5.4.6 Transformer Stations**

Many transformer stations support the electrical needs of building operations across Line 1. Most transformer stations were constructed with the building of Line 1 in 1941 and their design and appearance vary greatly across the site. Most transformers are located on concrete pads in chain-link fenced graveled areas. Some transformers are on wooden planks located on power poles. More recently designed transformers are located in a concrete dike area surrounded by chain-link fence and are contained in heavier housings. The transformers in the transformer stations were replaced when required, but the history of transformer replacement at each transformer station is not known.

PCBs used as coolant in transformers often leaked out of the transformer housings and onto the ground. Transformer stations to be sampled by TN&A were selected based on age, appearance of PCB staining, and design of transformers. For example, newer more recently built transformer stations containing transformers with reinforced housings surrounded by clean unstained dike concrete areas were not sampled. An exact number of transformer stations that have existed is not known.

##### **5.4.6.1 Transformer Station Sample Results and Conclusions**

TN&A sampled 24 transformer stations for PCBs at 0–1 ft and 1–2 ft intervals. Two sample locations, 116914 and 116925, reported Aroclor-1260 above detection limits but below RG.

Sample location 116914 by transformer station 1-169-15, south of Building 1-62, reported Aroclor-1260 concentrations at 5300 µg/kg at 0–1 ft and 3200 µg/kg at 1–2 ft.

Sample location 116925, by transformer station 1-169-27, detected 560 ppm Aroclor-1260 at 0–1 ft depth.

While sample location 116914 at transformer station 1-169-15 is below action levels for PCBs, further sampling is suggested in this area to confirm the absence of PCBs below action levels. No further sampling is suggested around other transformer stations.

## **5.5 Component Rest Houses (1-71, 1-72, 1-74, 1-75, 1-76, and 1-77)**

Component rest houses were temperature controlled to allow munitions to reach thermal equilibrium evenly between operations. Buildings 1-71, 1-72, 1-74, 1-75, and 1-76 were the first rest houses, built in 1941. Building 1-77 was built by AEC to apply thermal coating and drying of components. Historically, the areas around these rest houses appear never to have been sampled. Environmental contamination from these buildings, with the exception of Building 1-77, is unlikely. However, no data are available to support the notion that the soils around these buildings are below action levels.

Although contamination was judged to be unlikely, sample were collected for explosives and metals around the doorways of these buildings to confirm that these areas do not warrant additional investigation.

### **5.5.1 Component Rest House Sample Results and Conclusions**

TN&A collected samples from locations around doorways and drainage ways for each rest house. No TN&A sample locations reported results above action levels for metals or explosives. Samples collected from 1-74 and 1-76 areas reported explosives above detection limits but below action levels.

No further sampling is proposed at component rest houses.

## **5.6 X-ray Buildings (1-73 and 1-100)**

Buildings 1-100 and 1-73, which were used as X-ray buildings, housed equipment used to take X-rays of completed components to find flaws and to collect data needed to make improvements. X-ray Building 1-100 contained two 1,000,000-volt X-ray machines. X-ray Building 1-100 was also used to machine explosives during the QA process.

Building 1-12 also contained X-ray machines for employee training and for backup use. Sample results for this building are presented in Section 5.2.3.

The potential contaminants suspected at the X-ray buildings are metals. The primary metal of concern is silver from the X-ray film development processes.

Interviews indicate that there was no sump to collect wastewater from Building 1-100, and wastes were discharged by a pipe directly into a drainage ditch. In subsequent years, contaminated water flowed through aluminum-lined gutters to the Filter Building, 1-70.

### **5.6.1 Building 1-73 Sample Results and Conclusions**

The JAYCOR RI did not show that any samples had been collected around Building 1-73.

TN&A collected samples for explosives and metals from four locations in doorways and drainage ways around Building 1-73. Sample location 107301 reported RDX above RGs in a drainage ditch east of the building. Because this location is located in a drainage way that supports other buildings, it is possible that the explosives contamination originated from another source.

Sample location 107305, in front of the south doorway, reported RDX above detection levels with increasing concentrations down to 6 ft bgs.

Further sampling is proposed to delineate the area of concern at these locations.

## **5.6.2 Building 1-100 Sample Results and Conclusions**

One JAYCOR sample location reported silver at a concentration equal to its PRG around the northwestern side of Building 1-100. JAYCOR field screening sample results around the rest of the building did not show metals above screening levels.

TN&A collected samples for explosives, metals, and VOCs at three locations around Building 1-100. A former wastewater discharge pipe was identified by TN&A field personnel with help from current plant workers. Sample location 110001 is located at this pipe outfall. The depressional area at the outfall is covered with large slabs of broken concrete. Sample results at this location reported silver contamination above PRG. These data support historical drawings research and information obtained from interviews with former employees about wastewater from X-ray Building 1-100 being discharged into a ditch by pipeline.

TN&A sample location 110002 reported arsenic above RGs around the south side of Building 1-100.

Further sample locations are proposed to delineate around sample locations 110001 and 110002. See Figure 5 for areas of concern.

## **5.7 Wood and Metal Shops (1-01)**

Building 1-01 contains the wood/metal shops. From 1941 to 1947, Building 1-01 was used as an inert pour and maintenance shop. Wooden boxes were made in Building 1-01 during AEC operations for containing munitions before shipment. Specific metals operations are not known.

### **5.7.1 Building 1-01 Sample Results and Conclusions**

JAYCOR sample results around Building 1-01 reported RDX concentrations above RGs around the western side of the building near a sump. This sump has since been remediated and paved over with concrete.

TN&A sampled four locations around the doorways and drainage ways. The samples were analyzed for explosives, metals, and VOCs. Samples from sample location 100102 reported VOCs above detection limits.

TN&A sample locations did not report any contamination above action levels around Building 1-01.

No further sampling is proposed around Building 1-01.

## **5.8 Former AEC Assembly and Storage Buildings**

### **5.8.1 Former AEC Assembly Buildings**

There are six AEC assembly buildings (1-63-1 through 1-63-6) located on the northeastern side of Line 1. A seventh AEC assembly building (1-63-7) is located in the southwest side of Line 1. Buildings 1-63-1 through 1-63-6 were built in 1957. Building 1-63-7 was built in 1974. These buildings contain assembly rooms called cells. Through historical research it was discovered that a common waste management practice was to pump wastes to waste containers located outside the building. The time period for this practice is not known, but is believed to have been in the late years of AEC operations at Line 1. Sample results around these buildings or cells are presented below and in Figure 4.

Building 1-61 was built during AEC operations at Line 1 in 1951. The building has been designated by some building records as a “major caliber loading plant” and “assembly and shipping building.” The building was equipped with 12 operation bays and has below-ground and above-ground structures. The above-ground portion is barricaded with earthen embankments. This building has railway support. Historical records show that this building was used primarily as an assembly building. Because part of this building existed underground, groundwater had to be pumped into outside drainage ditches. Little is known about the operations at this building. It is known that wastes from loading or assembling operations were pumped outside into waste containers.

AEC storage buildings 1-64-1 through 1-64-5, 1-65-1 and 1-65-2, and 1-66-1 and 1-66-2 were added to support AEC operations over the years 1957 through 1974. Buildings 1-65-3 through 1-65-7 were added after AEC operations at Line 1. All of these buildings, with the exception of 1-66-1 and 1-66-2 (located on the southeastern side), are located on the western to northwestern side of Line 1. Explosives and components needed in the assembling of munitions were stored in these buildings. It is possible that other chemicals such as solvents and adhesives may also have been stored in these buildings. Little else is known about these buildings.

### **5.8.2 AEC Assembly Buildings Sample Results and Conclusions**

#### **5.8.2.1 Buildings 1-63-1 Through 1-63-7 Sample Results and Conclusions**

JAYCOR did not collect samples from around these buildings.

TN&A field personnel located piping labeled “waste” running from the cells and from the buildings, often times next to doorways. It was not verified if this piping is the same piping that carried wastes to the waste containers located outside the buildings.

TN&A collected samples for explosives and metals outside the nearest doorways from each of the assembly cells along a nearby drainage ditch. A dumpster labeled “explosives contaminated waste” on a dumpster pad was located on the south side of Building 1-63-7. The dumpster was connected to a hose that was connected to the building by piping similar to that found at the other assembly buildings.

Sample results from all locations did not show any results for explosives and metals above action levels. No further sampling is proposed for these buildings.

### 5.8.2.2 Building 1-61 Sample Results and Conclusions

No samples were taken during the JAYCOR RI around this building.

TN&A collected samples for explosives, metals, and SVOCs at five locations around doorways and drainage ways. Sample location 106103 was located in the area of a contaminated waste dumpster identified on a historical engineering drawing. A concrete pad believed to be the contaminated dumpster location was identified. This location did not report any parameters above action levels.

Sample Location 106105 reported arsenic just above the RG in a drainage way south of the building. Additional sampling is proposed to further delineate the area of concern at sample location 106105.

### 5.8.2.3 AEC Storage Buildings Sample Results and Conclusions

JAYCOR did not collect samples from locations around these buildings.

TN&A collected samples for explosives, metals, and VOCs at locations around these buildings, as shown in Figure 4. Sample locations 106504, 106503, 106501, and 106403 showed explosives results above detection limits. No sample locations reported any results above action levels.

No additional sampling is proposed around AEC storage buildings.

## 5.9 Filter Buildings (1-70 and 1-70-1)

Buildings 1-70 and 1-70-1 were built during AEC operations of Line 1 to treat explosives-contaminated effluent released from explosives component production buildings. Generally speaking, Filter Building 1-70 supported waste effluent from the southern half of Line 1 and Filter Building 1-70-1 supported the central to northern portion of Line 1. Major buildings supported by Filter Building 1-70 were machining Building 1-10 and 1-12. Filter Building 1-70-1 supported the two melt buildings (1-05-1 and 1-05-2).

These buildings contain clarifiers that removed explosives sludge and carbon filtration systems that removed dissolved explosives from the effluent. After the effluent passed through the carbon filtration system, it was discharged into a drainage way leading to the Line 1 impoundment. From personnel interviews, it was discovered that the explosives sludge from the filters was taken to the burning area and incinerated. These two areas pose an elevated risk for environmental contamination.

### 5.9.1 Building 1-70 Sample Results and Conclusions

Filter Building 1-70 was not sampled during the JAYCOR RI.

TN&A collected samples for explosives, and metals from three locations in drainage ways around Building 1-70.

Sample location 107004 reported the highest levels of RDX above RGs in the TN&A investigation. RDX was reported from this location above RGs in every sample taken from a ditch east of Building 1-70. The 1–2 ft depth interval contained the highest level of RDX

reported (660 mg/kg). The 2–4 ft depth interval reported an RDX concentration of 110 mg/kg. The last interval from the 4–6 ft depth at location 107004 reported RDX at 3.7 mg/kg, still above the RG. 2,4,6-TNT was also reported above RG at location 107004 from the 1-2 depth interval.

Sample location 107001 reported RDX above RG taken from the 2-4 ft depth interval.

Sample location 107002 reported RDX, 2,4,6-TNT, DNT, and HMX above detection levels but below RGs.

The drainage ways and the immediate area around Building 1-70 is considered an area of concern, as shown in Figure 5. Further sampling is necessary to delineate this area of concern.

### **5.9.2 Building 1-70-1 Sample Results and Conclusions**

JAYCOR sample results in the drainage ditch leading west from Building 1-70-1 showed levels of explosives and metals above RGs. JAYCOR noted that a liner of an unknown material was encountered while sampling in this drainage ditch. TN&A personnel did not encounter this liner.

TN&A collected samples for explosives and metals from three locations around building 1-70-1 and in the drainage ditch sampled by JAYCOR.

A cooling tower (1-155-1) area was also sampled by TN&A (see Section 5.10). Locations 107005 and 107006 detected explosives above detection levels but well below RGs. Location 107006 was located in the drainage ditch leading west from the building.

No further sampling is proposed for these locations.

### **5.10 Cooling Towers (1-155-1, 1-155-2, 1-155-3, and 1-155-4)**

Cooling Towers 1-155-1, 1-155-2, and 1-155-3 were installed by AEC and provided water recovery when water consumption was high. Cooling towers were located at Buildings 1-10 (1-155-2), 1-12 (1-155-3), and 1-60 (1-155-4) to provide cool water for air conditioning utilities and at 1-05-1 and 1-05-2. A double cooling tower (1-155-1) was installed to provide the necessary cool water for process operation. At other smaller air conditioning installations, such as Buildings 1-04 and 1-01, evaporative coolers were used.

Processes in the cooling towers reportedly released hexavalent chromium to Brush Creek during AEC operations. Hexavalent chromium was used as an additive to control corrosion and deposits in the cooling towers.

A water sample collected at Line 1 reported 0.77 ppm hexavalent chromium during 1971. The most restrictive quality standard was reported as 0.05 ppm.

The cooling towers have not been in operation for many years, possibly decades, and therefore have not recently contributed chromium contamination to the surface water. Furthermore, the impoundment area of Brush Creek near Line 1 was remediated by CDM in 1995. TN&A collected samples in drainage ditches leaving the proximity of the cooling towers and traveling in the direction of Brush Creek. These samples will assist in determining if any contamination persists in Brush Creek from the cooling towers. The results from this sampling are presented in Section 5.11.

### **5.10.1 Cooling Towers Sample Results and Conclusions**

No JAYCOR samples were taken around Cooling Towers 1-155-1, 1-155-3, and 1-155-4. JAYCOR did not detect any parameters above action levels at any sample locations around 1-155-2.

TN&A sampled for explosives and metals around each cooling tower. No sample locations reported any results above action levels. No additional sampling is recommend.

## **5.11 Drainage Ways and Impoundments**

The network of drainage ways located near the majority of the buildings on Line 1 has a higher potential for contamination from explosives and metals than any other area. Based on interviews with former employees, the drainage ways around buildings were used to carry effluent to Brush Creek. Washing out buildings into drainage ditches (“washdown”) was a common waste disposal practice, as explained by former employees. During AEC operations, Line 1 became the largest source of explosives-contaminated waste to Brush Creek. Water in these drainage ditches was reported to have been red with TNT contamination.

Research conducted by TN&A indicates that not all drainages are likely to be contaminated.

Data results presented in the following section are for the 26 site-wide sample locations designated as (10DDXX) collected specifically for investigation of Line 1 drainage ways. For TN&A and JAYCOR samples collected in drainage ways near buildings, these results are considered as area building samples and are presented with the preceding building sample results section.

Interviews with former employees indicated that sediment ponds were located upgradient from the Line 1 impoundment at Brush Creek prior to 1957. These ponds were reportedly less than an acre in area and 1 or 2 ft deep and were believed to be located somewhere between the melt buildings conveyors. No historical drawings or aerial photographs were found identifying the existence or locations of these former sediment ponds.

These sediment ponds may have existed somewhere along the drainage path from the melt buildings to Brush Creek, in particular the areas where the drainage ways run between the conveyors from the melt buildings.

As part of the drainage way sampling, samples were collected periodically from all drainage ways leading from the melt buildings, between the conveyors, and then out to Brush Creek.

### **5.11.1 Drainage Ways Sample Results and Conclusions**

TN&A collected samples for explosives and metals from 26 locations in drainage ways, as shown in Figure 4, and designated with a “DD” in the location ID. These samples were collected in the main drainage ways that lead to Brush Creek in an effort find evidence of explosives and metals contamination that could have resulted from washout being carried to Brush Creek. Metals were collected at the 0–1 ft depth interval. Explosives were collected at 1–2 ft, 2–4 ft and 4–6 ft depth intervals.

Barium was detected above it’s PRG at 10DD19. No other location detected metals above action levels.

Samples 10DD16 and 10DD17 were collected from Brush Creek. These locations reported explosives above detection limits but below RGs.

Explosives were reported above detection limits at seven locations but were not reported above RGs in any of these 26 locations. One explanation for this could be that explosives biodegradation may have occurred over the decades. Section 7.0 discusses the action of explosives in the environment.

Unless historical information can be found revealing the locations of the small sediment ponds mentioned by former employees, field screening grid sampling followed by laboratory sample collection may be needed in the large area between the conveyors.

Additional sampling is proposed to further delineate the area of concern around sample location 10DD19.

## 6.0 FIRING SITE AREA BY AREA SAMPLE RESULTS AND CONCLUSIONS

The following section contains a historical area-by-area summary along with sample results for the Firing Site. The Firing Site has been broken up into building groups based on their historical operations. The building groups are further broken down into individual buildings where necessary.

Only laboratory sample results are discussed in this section because no field screening samples were collected at the Firing Site by TN&A.

Also, in developing sampling rationale, special attention has been given to the sample results obtained from the 1996 JAYCOR Revised Draft Final Remedial Investigation. TN&A samples were collected to evaluate each site as well as confirm JAYCOR results. All detectable JAYCOR data are presented in Appendix A.

This section summarizes the sampling rationale and historical information in an area-by-area format. To provide direction, references have been added to guide the reader to where more detailed information can be found. Throughout the following sections the total area encompassing all Firing Site structures are referred to as the Firing Site (FS); individual firing site locations are referred to as, for example, FS-(*site number*).

This section is supported by the following tables:

Table 1	Line 1 Site and Firing Site Sample Locations and Collection Information
Table 2	Soil Remediation Goals (RGs) and Preliminary Remediation Goals (PRGs)
Table 3	Development of IAAAP Background Levels from JAYCOR Background Data
Table 6	Firing Site Results Above RGs & PRGs*
Table 7	Firing Site Results Above Background

\* No TN&A sample results were detected above RGs or PRGs at the Firing Site. JAYCOR detected RDX above RG at one location. (See Figure 8).

### 6.1 FS-1 and FS-2

FS-1 and FS-2 were grouped into an area of concern because of their proximity to one another and because both buildings were administrative and storage buildings. FS-2 was constructed in 1948 and was used as an inert storage facility. In 1952, FS-1 was constructed and served as an office and administrative building. Interviews with former employees indicated that an X-ray film processing machine was used in FS-1 to develop film of test shots performed at the Firing Site Area. From the interviews and drawings, it was learned that a septic tank served FS-1 and FS-2. It was also learned that process water from an X-ray film developing machine at FS-1 may have been drained into the septic system. Historical investigations did not produce any evidence that radiological materials, explosives, or solvents were handled at either of these buildings.

#### 6.1.1 FS-1 Sampling Results and Conclusions

JAYCOR did not collect samples at FS-1.

TN&A samples at the south side of FS-1 near the front doorway and a sewer line did not show any contaminants above action levels (RGs/PRGs).

Based on the low probability of explosives or metals contamination at FS-1, no additional sampling is recommended.

### **6.1.2 FS-2 Sampling Results and Conclusions**

JAYCOR did not collect samples at FS-2.

TN&A collected samples for metals and VOCs in front of the loading dock at FS-2 and around the septic tank east of FS-2. No sample results around the loading dock reported contaminants above action levels.

Four locations were sampled around the southern side of the FS-2 septic tank. No samples reported contaminants above action levels. No further sampling is proposed for FS-2.

## **6.2 FS-3, FS-4, and FS-5**

Between 1948 and 1952, three general purpose storage magazines were constructed. FS-3, FS-4, and FS-5 were grouped into an area of concern due to their proximity to one another and because all three buildings were used for storage of munitions and radiological materials. No actual ordnance testing was done at any of these facilities; therefore, the area is not suspect for contamination. From interviews conducted, it was learned that during AEC operations between 1965 and 1973 components for the hydro-shots were assembled at FS-5. Presently FS-3 is used for detonator storage, FS-4 is used for warhead booster and TNT storage, and FS-5 is used to store inert materials. There is an environmental chamber in FS-5, which is occasionally used to temporarily store finished products.

### **6.2.1 FS-3, FS-4, and FS-5 Sample Results and Conclusions**

JAYCOR locations in the areas around FS-3, FS-4 and FS-5 did not detect contaminants above action levels (RGs/PRGs).

TN&A collected samples for explosives and metals around doorways and drainage ways. All samples reported parameters below action levels. No additional sampling is needed around the areas of FS-3, FS-4, and FS-5.

## **6.3 FS-6, FS-7, and FS-8**

During many of the years at IAAAP, especially during AEC operations, employees had restricted access on the plant and were given information only on a need-to-know basis. Consequently an employee may have very specific knowledge of a process or area where he worked but know nothing of any other process or area outside of his job. Because of this, very little is known about FS-7. FS-7 is shown on engineering drawings (TN&A Drawing No. 2000114-5050-TF-1972-S-0061.TIF) as an observation bunker; however, no one interviewed knows anything about FS-7, nor is it listed in any of the documents reviewed. Similarly, very little is known about FS-8. It is assumed that FS-7 and FS-8 were support structures for FS-6.

FS-6 was constructed in 1948. The date of construction for FS-7 is unknown. FS-6, FS-7, and FS-8 were grouped into an area of concern because of their proximity to one another and because explosive testing was done at these locations. Interviews conducted with Firing Site Area personnel indicate that FS-6 was the primary testing area until FS-14 was built in 1972. Drawings show an observation bunker and test-fire pad at FS-6. Plane wave lens shots were tested at FS-6. These plane wave lens shots were used to research explosive detonation waves. The explosives used in these shots were Composition B and barium nitrate. The COCs of the plane wave lens shot are the explosives associated with this type of shot. After the completion of FS-14 in 1972, the plane wave lens testing ceased at FS-6 and mines were tested. Presently FS-6 is active for the testing of ordnance currently produced at IAAAP.

Little is known about FS-7 and FS-8. Engineering drawings show them to be observation bunkers. FS-8 was constructed in 1952.

### **6.3.1 FS-6 Sample Results and Conclusions**

JAYCOR did not report any samples above action levels at FS-6. TN&A sampled for explosives and metals at four locations at FS-6. Explosives were detected above detection limits but below RGs north of a firing pad. No samples at FS-6 reported results above action levels.

No additional sampling is proposed for FS-6.

### **6.3.2 FS-7 and FS-8 Sample Results and Conclusions**

JAYCOR did not report any contaminants above action levels at FS-7 or FS-8. TN&A collected samples from one location in a drainage way located in front of former FS-7 for explosives and metals. Sample results were normal for background. TN&A did not collect any samples around the former FS-8 site.

No additional sampling is proposed at FS-7 or FS-8.

## **6.4 FS-9, FS-10, and FS-11**

FS-9, FS-10, and FS-11 first appeared in an aerial photograph dated 1941. These firing sites were grouped into an area of concern because of their proximity to one another and the explosives testing done at these locations. Due to tight security measures of Firing Site operations and a lack of living personnel with knowledge of this area, little is known about these three sites. Drawings show that FS-9 was an underground observation bunker. The bunker is believed to have been used in support of testing at the test-fire pad at FS-10.

FS-10 is an underground bunker with a test-fire pad on the surface. This area matches descriptions of the “old FS-12” given by interviewees. It is assumed that FS-10 is the “old FS-12.” Hydroshots were not conducted at FS-10 (“old FS-12”). Little information is available on FS-10 and operations conducted there.

FS-11 was an underground high-explosive supply magazine, and the probability of contamination at this location is low. During a site walkover by TN&A personnel in November 2000, remnants of an underground bunker (FS-11) were found.

#### **6.4.1 FS-9, FS-10, and FS-11 Sample Results and Conclusions**

JAYCOR locations at FS-9, FS-10, and FS-11 did not report any sample results above action levels. TN&A collected samples from seven locations around these areas. FS-9 was sampled for explosives, metals, and PCBs. FS-10 and FS-11 were sampled for explosives and metals. TN&A samples at these locations did not report any results above action levels.

No further sampling is proposed for FS-9, FS-10, or FS-11.

#### **6.5 FS-12**

FS-12 was constructed by AEC in 1964 and used to conduct hydro-shots. After AEC turned over operation of the Firing Site to the Army in 1975, FS-12 was used for testing conventional weapons. Until November 2000, FS-12 was used for QA testing of TOW and Hellfire missiles. The discovery of DU in November 2000 at the site halted all testing at FS-12. The DU contamination appears to be a result of hydro-shots.

During the hydro-shot explosion, the DU would be scattered several hundred feet from the firing point at FS-12. The records of hydro-shot testing at FS-12 report that 701 hydro-shots were performed between December 1965 and December 1973. These tests reportedly dispersed about 4,000 kg (about 8,870 lb) of DU.

Explosives samples will be taken at 10 locations at FS-12. Three of the sample locations are next to the JAYCOR locations to confirm JAYCOR's identification of explosives. One location is near the firing-pit where there is likely to be explosives and metals contamination from test firing of ammunition.

Drawings (TN&A Drawing No. 2000114-5050-1999-S-0021.TIF) and aerial photographs (TN&A photograph 2000011-4210-1990-S-0001.TIF) show the Wide Area Munitions (WAM) site located east of FS-12. These structures were visible in the 1983 and 1990 aerial photographs but were no longer present in the 1994 aerial photographs. This area consisted of three or four unlined pits that were approximately 6 ft square by 6–8 ft deep. The area is also known as the Total Containment Explosive Firing Site. Interviews of Firing Site workers indicated that mines were tested in the pits and that water in the bottom of the pits was red from explosives.

Engineering drawings and interviews confirm that there was an X-ray bay at FS-12. It is known that the X-ray was used to observe the hydro-shots conducted in the 1960s and 1970s. Metals sampling will be conducted at this site.

Per USACE-Omaha direction, TN&A conducted a very brief and informal survey of FS-12 in November 2000. Eleven pieces of DU-238 were found. These pieces ranged in size from slivers a fraction of an inch long to chunks 6 in. long by 2 or 3 in. thick. The DU was found scattered across the Firing Site, up to 286 ft from the FS-12 bunker. The majority of the pieces were found buried 3 to 12 in. in the ground. AO safety personnel disposed of the DU found at FS-12.

Before turning the Firing Site over to the Army, AEC tested soils at FS-12 for radioactivity and contracted for soil excavation to remove contaminated soil from around the firing point at FS-12. Soil was reportedly excavated to a depth of 15 ft at the firing point and from 1 to 2 in. from the surrounding area (including the WAM site). The volume of soil and debris removed is reported

as 86 cubic meters (112 cubic yards). The drummed material was shipped offsite to Nuclear Engineering Company in Sheffield, Illinois, for disposal as radioactive waste.

### **6.5.1 FS-12 Sample Results and Conclusions**

NO JAYCOR sample locations at FS-12 reported explosives or metals above action levels. TN&A collected samples for explosives and metals at 10 locations around FS-12, as shown in Figure 8. No TN&A sample locations reported contaminants above action levels in any sample at FS-12.

Sample locations TFS12038 and TFS12039 located in the area of the former total containment firing site, east of FS-12 Building, reported explosives above detection limits. TFS12029, believed to be located in the former “drag off pit area” north of Firing Site 12 Building also reported explosives above detection limits. All of the sampling locations at the Firing Site reported explosives below RGs.

Since FS-12 pit areas have been backfilled, additional sampling is suggested for explosives at lower depths down to 10 ft in an effort to identify these former areas. Contour information of these former pit areas was not identified during the TN&A investigation.

## **6.6 FS-14**

FS-14 was used for test-firing ordnance. Two test-fire chambers are located on the site. Little information was available for determining exactly what was tested at FS-14 or when testing took place. It was learned from interviewees that plane wave lens shots and tile shots were performed at FS-14. Tile shots consisted of a relatively small amount of conventional explosives and boosters. The tile shots were conducted later in AEC operations (interviewees could not give exact dates).

### **6.6.1 FS-14 Sample Results and Conclusions**

One JAYCOR sample location reported explosives RGs, as shown in Figure 8.

TN&A collected samples for explosives and metals from eight locations around FS-14. Samples from locations FS14048 and FS14049 reported RDX above detection limits. TN&A samples did not report explosives or metals above action levels at FS-14. TN&A did not confirm the results from the JAYCOR sample location above RGs for explosives.

Further sampling is not suggested at FS-14.

## **6.7 FS-15**

FS-15 is an ammunition quality test-fire facility. Engineering drawings show a recessed test fire site. Little is know about FS-15 due to operational security during AEC operations and a lack of people with knowledge of activities at the site.

### **6.7.1 FS-15 Sample Results and Conclusions**

JAYCOR samples collected around FS-15 did not report any explosives or metals above action levels. TN&A collected samples for explosives and metals at six locations around FS-15, as

shown in Figure 8. Samples from these locations did not report explosives above detection limits. Metals were not detected above background.

No further sampling is proposed for FS-15.

## 7.0 FATE AND TRANSPORT OF SELECTED CONTAMINANTS

Contaminants that are present in environmental media in excess of risk-based PRGs might be expected to represent threats to the health of exposed persons at Line 1 and Firing Site if the pattern and duration of contact is sufficiently great. However, uncertainty surrounds the degree of impact because of the capacity of some contaminants to move from one medium to another, or to become degraded by one or more biotic and abiotic processes. This uncertainty would be enhanced where future impacts are being projected from current or historical data-gathering activities. The extent to which each process is in operation at any given time will depend on the physical-chemical characteristics of the compound, the geophysical and geochemical characteristics of each medium, and the presence or absence of suitable microflora. As described in Section 1.2, the soil at OU 1 is characterized by 3 to 15 ft of loess material overlying a zone of glacial till, a soil horizon that may extend in some places to a depth of 50 ft bgl. Consisting predominantly of clay, though with interbedded lens of sand and silt, the glacial till may present only a partial barrier to the downward movement of water soluble soil-borne contaminants.

Since the regional hydrogeology is marked by a shallow drift aquifer less than 10 ft bgl, these contaminants are likely to leach to this aquifer to some extent. This groundwater in turn is thought to outcrop to local surface water bodies and, to a limited extent, serve as a recharge to the bedrock aquifer. Taking a subset of environmentally important substances that are likely to represent the risk-drivers at the Line 1 and Firing Site as a result of part or current practices at the site, the following paragraphs summarize what is known about their potential to move from one medium to another or become degraded. Substances under consideration include, among the explosives, RDX, TNT, HMX, and 1,3,5-trinitrobenzene; among the SVOCs, carbazole, dibenzofuran, chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene indo(1,2,3-cd)pyrene, and naphthalene; and, among the metals, lead, barium, and chromium. Secondary information sources used for this discussion include Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, Hazardous Substances Data Bank (HSDB) records, and the review *Nitroaromatic Munition Compounds: Environmental Effects and Screening Values* (Talmage et al., 1999).

### Explosives

Military grade RDX (containing about 10 percent HMX by weight) has been a widely used explosive since the early years of World War II, when it began to either replace or supplement TNT as the primary ingredient in shells, bombs, and detonators. As discussed earlier in this document, a pattern of manufacturing and assembling practices has resulted in its release to the environment in considerable amounts at IAAAP and other military sites. Soil concentrations of up to 13,900 mg RDX/kg are reported by Talmage et al. (1999) for some military sites, with levels of the compound in groundwater in the ppm range.

Although RDX has only low to moderate solubility in water (38.4 mg/L at 20-25°C), the compound has a low absorption coefficient for soils and sediments and, thus, will migrate to the shallow groundwater at IAAAP to some extent. However, RDX has an estimated vapor pressure of  $1-4 \times 10^{-9}$  mm Hg at 25°C, a low value implying that partitioning to air is unlikely. Photolysis is a potentially important process for degrading RDX in either air and/or process waste water (pink water), since the compound can absorb ultraviolet light strongly at wavelengths between 240 and 250 nm. In addition, biodegradation of RDX is likely to occur in soils and sediments at IAAAP, since the process has been simulated under the anaerobic

conditions that are typical of clay, assuming the presence of a number of microbial isolates and mixed cultures. For example, ATSDR (1995a) reports that the process went to completion in 5 days or less in bench-top experiments. Thus, when RDX was incubated in an anaerobic test system containing sewage sludge and mixed cultures in nutrient broth, its disappearance was accompanied by the formation of a sequence of metabolites including hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine (MNX), hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine (DNX), hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX), hydrazine, 1,1-dimethyl-hydrazine, 1,2-dimethyl-hydrazine, formaldehyde, and methanol.

In a similar manner to RDX, an important route by which surface water, groundwater and surface soils become contaminated with TNT historically has been the massive aqueous effluents of rinse water (pink water) from explosives manufacturing. However, TNT has a higher water solubility than RDX (130 mg/L at 20°C) and consequently may be more likely than the latter compound to remain in solution in the surface water bodies at Line 1 and Firing Site and less likely to partition to soils and sediments (USACHPPM, 2000). Nonetheless, large amounts of TNT have been detected in soil at this and other AAPs because of the large-scale production of the compound over many years. However, TNT is not expected to bioaccumulate or biomagnify in terrestrial systems.

Biotransformation in soil is an important fate and transport mechanism for TNT, the compound being reduced by microbial action. The process appears to occur through successive reduction of the nitro groups but with conservation of the compound's aromatic ring. Bacterial genera identified in these reactions include species of *Pseudomonas*, *Escherichia*, *Bacillus*, *Citrobacter*, *Enterobacter*, *Klebsiella*, *Veillonella*, and *Clostridium*. Microbial transformation of TNT leads to a variety of reduction products, including 2-amino and 4-amino dinitrotoluene and azoxydimers, though some oxidation products have been identified also. Biological transformation by bacterial and fungal species occurs slowly in the environment, with slightly higher rates in the presence of other carbon sources.

In a manner similar to that of RDX, photolysis is another process that can affect the fate and transport of TNT in the environment. Numerous transformation products have been identified in pink water, predominantly 1,3,5-trinitrobenzene, 4,6-dinitroanthranil, 2,4,6-trinitrobenzaldehyde, and 2,4,6-trinitrobenzotrile, in addition to several azo and azoxy derivatives formed by the coupling of nitroso and hydroxyamine products.

HMX, a more powerful explosive than TNT, has been used as a trigger mechanism, as a component in plastic explosives, and in rocket fuels (ATSDR, 1997a). Important physical-chemical characteristics relevant to its fate and transport in the environment include the vapor pressure and Henry's Law constant, both of which are sufficiently low ( $3.33 \times 10^{-14}$  mm Hg and  $2.60 \times 10^{-15}$  atm.m<sup>3</sup>/mole, respectively) to indicate that HMX is very unlikely to be released to the air as a vapor. However, aerial dispersion of the compound while adhering to soil or dust particles has been implicated as a likely mechanism by which the compound can be released to the atmosphere (ATSDR, 1997a). Thus, with a low log soil organic carbon-water partition coefficient of 0.54, HMX has the potential for high mobility in soil and may be leaching into shallow groundwater of Line 1.

Photolysis appears to be the dominant process by which HMX is broken down in the environment, with a reported first order photolytic rate constant of  $0.15 \text{ days}^{-1}$ . This suggests that an aqueous concentration of 0.5 mg/L HMX will have a half-life of 4–5 days when exposed

to natural sunlight. Primary products of this process include nitrate, nitrite, and formaldehyde. By contrast, biodegradation/biotransformational processes involving bacteria or other microflora are extremely slow, though the formation of 1,1-dimethyl hydrazine has been demonstrated as a result of anaerobic degradation.

The compound 1,3,5-Trinitrobenzene (1,3,5-TNB) is another substance that has been released to the environment during the manufacture of explosives at IAAAP. The compound is closely related structurally to TNT, of which it is a manufacturing byproduct and an environmental degradation product. The compound 1,3,5-TNB has an estimated vapor pressure of  $3.2 \times 10^{-6}$  mm Hg at 25°C, a low value implying that partitioning to air is unlikely (ATSDR, 1995b). The compound has been identified in both surface water and groundwater, and significant concentrations in sediments have been detected in 1,3,5-TNB-contaminated waste streams at some AAPs.

As noted above, TNT will undergo photolysis to produce 1,3,5-TNB in aqueous solution, but the daughter compound is resistant to further photolytic degradation. Talmage et al. (1999) report  $K_{oc}$ s in the range 76–520, values that would predict a moderate degree of adsorption of 1,3,5-TNB to suspended sediments, and high to moderate soil mobility. The compound 1,3,5-TNB is subject to microbial degradation, but the process appears to be limited to the compound's nitrogenous moieties. Thus, aerobic metabolism of 1,3,5-TNB by *Pseudomonas* sp. produces 1,5-dinitroaniline, dinitrobenzene, 5-nitrobenzene, and ammonia. This indicates that 1,3,5-TNB is probably not used as a carbon source by this organism, since no further breakdown was described.

### Semivolatile Organic Compounds

Benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, ideno(1,2,3-cd)pyrene, and naphthalene are a few of a large number of polycyclic aromatic hydrocarbons (PAHs) formed during the incomplete combustion of organic matter. Though structurally related, the compounds display considerable heterogeneity in the number and spatial arrangement of their fused aromatic rings. Mixtures of PAHs are ubiquitous in the air as a result of stack emissions, fly ash, smoke from household wood and coal fires, cigarettes, barbecue grills, automobile exhausts, etc. They are also components of used oils, asphalts, roofing tar, and other substances of a similar nature. The compounds are typically released to the air through stack emissions and then may be secondarily dispersed to other media and detected at environmental sites. Seventeen PAHs including benzo(a)pyrene have been identified as being especially important for environmental monitoring and compliance purposes (ATSDR, 1995c). These can be further discretized by whether or not they have been demonstrated or are thought likely to induce or promote tumor formation in experimental animals. Benzo(a)pyrene is the most well-studied PAH, a cancer-inducing substance whose toxicological data serve as quantitative benchmarks for the entire carcinogenic subgroup. Thus, whereas toxicological data on the carcinogenicity of other PAHs are poor, quantitative estimates of their carcinogenicity can be expressed relative to that of benzo(a)pyrene through the use of toxicity equivalency factors (TEFs).

There is an extensive bibliography on the dispersion of PAHs such as benzo(a)pyrene in environmental media, with HSDB (2002) and ATSDR (1995c) providing summaries of the available information. The fact that benzo(a)pyrene and its analogues have been detected in all environmental media and in foodstuffs (HSDB, 2002) attests to the compounds' ability to

become widely dispersed when released to the atmosphere, as well as to the comparative ease with which they can become taken up into the food chain.

ATSDR (1995c) discusses the potential for PAHs such as those detected at IAAAP to become dispersed throughout environmental media following their release to the atmosphere in combustion emissions. Natural sources of PAH emissions include forest fires and volcanoes, while anthropogenic sources include the residential burning of wood; generation of industrial power; incineration of waste; production of coal tar, coke, and asphalt; and exhaust emissions from automobiles, among many others. Typically, a complex mixture of PAHs will be released by these processes of which benzo(a)pyrene is but a single, and not necessarily the most heavily represented, component. However, benzo(a)pyrene predominates among the PAHs released in cigarette smoke, with detected amounts of 5–80 ng/cigarette (ATSDR 1995c).

Airborne PAHs undergo widespread dispersion in the atmosphere but will ultimately become deposited in surface water or soil as a result of wet or dry deposition. In surface water, the compounds can volatilize, photolyze, oxidize, biodegrade, become bound to suspended particles or sediments, and/or bioaccumulate in aquatic organisms. However, the combined low water solubility and vapor pressure, and high octanol-water partition coefficient ( $K_{ow}$ ) of most PAHs suggest that the compounds will partition to the soil compartment primarily, sediment secondarily, and air, water, and biota much less heavily favored.

The capacity for PAHs to undergo abiotic degradation in the atmosphere, for example, by photooxidation, is governed to a large extent by the physical nature of the compound. Thus, ATSDR (1995c) reports that those compounds absorbed to soot are more resistant to photochemical reactions than pure compounds. However, photolysis may be an important process by which PAH molecules in water can be degraded.

A number of microbial genera are able to breakdown PAHs to related but not necessarily simplified structures. In addition, some algae and fungi are effective, with biodegradation being an important process by which PAHs can be removed from soils and sediments.

As summarized in HSDB (2002), carbazole is another compound that, like the PAHs, is released to the atmosphere in emissions from incomplete combustion of organic matter, including waste incineration, aluminum manufacturing, tobacco smoke, and the like. Photochemical degradation of carbazole appears to be rapid, and wet and dry deposition to soil permit its ready biodegradation in the presence of suitable microflora. Similar processes are thought to occur in surface water bodies.

The physical-chemical characteristics of dibenzofuran argue strongly for the ready removal of the compound from a water column through absorption to sediments and particulate matter. Any unbound dibenzofuran would also have the capacity to volatilize in air (gas-phase). Given the high affinity of the compound for particulate matter, dibenzofuran is not expected to display much movement in soil. Photodegradation and biodegradation of the compound in soils have been demonstrated, but the processes are slow.

## **Metals**

Lead is a naturally occurring element that is persistent in the environment (ATSDR, 1997b). Lead released to the atmosphere will become deposited in soil, surface water and sediments as a result of wet or dry deposition. Moreover, inorganic lead compounds have a high affinity for

organic matter and, thus, may become strongly sorbed to soils and sediments. The extent to which lead forms complexes and precipitates in soil depends on the soil type. Thus, in soil with a high organic content and near-neutral pH, the element may form organic lead complexes. However, where the organic content is less, hydrous lead oxide complexes may form, or the element may sediment as the carbonate or phosphate. Entrainment of soil particles is another route of lead transport. As discussed in ATSDR (1997b), movement of elemental or inorganic forms of lead to IAAAP's drift aquifer will be very slow in all but the most acidic of conditions.

The element has the potential to enter the food chain through bioaccumulation. Notwithstanding the tendency of the element to adsorb to soil particles, lead also may be taken up into plants if the geophysical and geochemical characteristics of the soil are suitable. Many plants that take up lead from soil will represent a human health threat if they are harvested as a source of food.

Though chromium occurs naturally in the earth's crust, the element is released to the environment in large quantities as a result of mankind's activities. Electroplating, leather tanning, and textile industries are major sources of chromium release to the environment, mainly as the insoluble chromium (III) oxide. However, chromium (VI) has been detected in fly ash from coal-fired power plants and from sites where chromium is manufactured or used.

Chromium occurring in the atmosphere as particulates will be deposited to surface water or soil as a result of wet or dry deposition. Most of the chromium in lakes and rivers will ultimately be deposited in the sediments. The majority of the chromium in soil is present as the insoluble oxide that would tend to be immobile in that matrix. However, surface runoff can transport soluble and precipitated chromium alike to surface water. ATSDR (1998) discusses at some length the potential for chromium to transition between chemical species depending on the geophysical-geochemical characteristics of the environmental matrix. For example, the fate of chromium in the soil will fluctuate depending on the redox potential and the pH of the soil. Thus, the reduction of chromium (VI) to chromium (III) is facilitated by low pH and anaerobic conditions.

As summarized in ATSDR (1990) and HSDB (2002), barium occurs naturally in the earth's crust, mainly as the sulfate or carbonate. The element enters the environment naturally through the weathering of rocks and minerals, mechanisms that are far surpassed in quantity by releases associated with industrial processes. Barium released to the atmosphere will be largely in the particulate form, the compounds being subject to wet and dry deposition to land and surface water, leaching to groundwater, absorption to soil and sediments, and biomagnification in terrestrial and aquatic food chains. Because of the wide range of commercial applications of barium compounds, large-scale industrial emissions will result from the mining, refining, and production of barium ores and chemicals. Another source of airborne barium is fly ash from coal-fired power stations.

Barium deposited to surface water bodies is likely to already be or rapidly become insoluble in the presence of sulfate ions. However, barium carbonate can become the dominant species at high pH. The element reacts with metal oxides and hydroxides in soil and subsequently becomes adsorbed to soil particles. Bioaccumulation of barium can take place into plants and aquatic organisms from soils and sediments.

## 8.0 CONCEPTUAL SITE MODEL

The conceptual site model (Figure 10) of Line 1 and Firing Site is based on what is currently understood about (1) existing levels of contamination at the site, (2) past and ongoing practices and processes that may have caused releases of contaminants to the environment, and (3) existing and potential patterns of land use at or in the vicinity of the Line 1 and Firing Site. Thus, the model identifies existing sources of contamination at the Line 1 and Firing Site, visualizes the mechanisms by which substances can become released from these sources, evaluates all the possible pathways by which contaminants can move through and between media, and shows how receptors may become exposed to contaminants by contact with these media during the course of their daily lives.

Evaluating past practices of handling explosives and ancillary materials at Line 1 allows the suggestion that the primary sources of contaminants are the process wastewater and effluents from manufacturing. Contaminants may have been released from these sources to the environment by leaks from pipelines, spills while transferring chemicals from one container to another, sedimentation and (re)dissolution as the material is transferred through the process stream, and building washout at the end of a process batch or during routine maintenance. These processes are likely to result in contamination to soil, dust, and surface water as the primary exposure media.

Evaluating past and current practices of test firing munitions at the Firing Site have resulted in the release of contaminants contained in munitions into the environment. The process of munitions testing is likely to result in contamination to soil, dust, and surface water as the primary exposure media.

The conceptual site model visualizes these media as capable of giving up their substances to secondary exposure media through a combination of erosion, infiltration, wind dispersion, percolation, sedimentation, and runoff. The question of which of these mechanisms has primacy will depend on the climate, topographical and geological characteristics of the site, and the physical-chemical properties of the contaminants themselves. However, the consequence of these secondary transport mechanisms will be a suite of secondary exposure media; their potential for affecting receptors will depend on the current and hypothetical future uses of the site.

In this case, onsite soil, onsite surface water, offsite surface water, onsite sediments, and groundwater are all likely to have been impacted by past practices at the Line 1 and Firing Site; therefore, they are evaluated in Figure 10 for ways in which they may impact current and future receptors. The current and future land use of Line 1 is likely to continue load, assembly, and pack (LAP) operations in which explosive substances are assembled into ordnance. The Firing Site will continue to test these ordnances. Therefore, the most likely current and future receptors will be onsite personnel and construction workers. These receptors may become exposed to contaminants through incidental ingestion, inhalation, or dermal contact with onsite soil, or through dermal contact with onsite surface water and (less likely) sediments.

The conceptual site model also visualizes the possibility that contaminants could move offsite in surface water or groundwater. Should that happen, offsite residents may become exposed to IAAAP-specific contaminants, e.g., if someone were to obtain his domestic water supply from a well tapping a contaminated aquifer. In such a case, exposure would arise as a result of

ingestion, inhalation of volatiles while showering, and dermal contact. Where contaminants move off site in surface water, the possibility exists that contaminants may enter the food chain, become accumulated into higher trophic receptors such as fish, and then be consumed by recreational or subsistence fishermen. The conceptual site model shows the latter pathway as a potentially complete pathway that is, nonetheless, unlikely to be an important contributor to carcinogenic risk or non-cancer hazard.

Data needed to characterize the identified contaminant migration pathways include sufficient sampling and chemical analysis information to delineate the media-specific nature and extent of contamination, especially in those secondary exposure media that trigger the most important completed pathways. To characterize the groundwater that could become drinking water for off-site residents, groundwater sampling analysis data should be supplemented by any available information monitoring the chemical concentration of contaminants at the faucet, and/or by the application of a fate and transport model.

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