DRAFT HISTORICAL SITE ASSESSMENT

GSA PROPERTY
WATERTOWN, MASSACHUSETTS

CONTRACT NO. DACA33-97-C-0023

DERP PROJECT NO. DO1MA001902
DEP CASE NO. 3-02722

OCTOBER 2000

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WATERTOWN, MASSACHUSETTS

Prepared for:

Department of the Army
U.S. Army Corps of Engineers, New England Division
Concord, Massachusetts

Prepared by:

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EXECUTIVE SUMMARY

This Historical Site Assessment summarizes the history and previous surveys conducted on the Northeast Area of the Watertown Arsenal, formerly known as the Federal Property Resources Center, and currently owned by the General Services Administration (GSA) and known as the GSA Property. This document is based primarily on radiological data and reports prepared by others; Harding ESE has not collected any additional site data during the preparation of this HSA. All reported observations and conclusions are those included in the documents that have been reviewed and, except where noted, do not reflect any additional interpretation by Harding ESE. Harding ESE comments have been included as italicized text. Under a related effort, site-specific release criteria will be developed for various plausible re-use scenarios for the GSA Property. The HSA will be used to determine the suitability of existing site characterization data to support the site-specific release criteria, and to identify data gaps.

The introduction of radiological material at the site began sometime in the 1940s or mid 1950s, and residue from this material still exists on the site. An area in the northern third of the site, known as the burn area, was used by the Army Materials and Mechanics Research Center (AMMRC) for the burning of depleted uranium (DU) to produce uranium oxide (U_3O_8), which results in a significant decline in mass, as well as stabilizing the DU, which is a pyrophoric material at small particle sizes. This material was then shipped off-site for disposal. DU contamination of the surface and subsurface soil in the burn area and surrounding areas occurred during these activities, which included the burning of DU chips on a concrete pad and the transport of the chips and burned material to and from the pad. The DU scrap was produced by machining, manufacturing, and testing conducted at the Arsenal. Because the groundwater interface at the GSA site is very shallow, DU residue is present in the saturated subsurface soil zone. In addition, the northern portion of the site exhibits signs of the presence of uranium ores and tailings, probably as a result of the disposal of materials from uranium ore research undertaken at the Arsenal by the Massachusetts Institute of Technology (MIT) and American Cyanamid during the late 1940s and early 1950s.

Numerous surveys have been performed to characterize the chemical and radiological residues present at the site. In 1966, 1967 and 1973, radiological surveys were performed in preparation for transfer of the property to GSA ownership. The site was released for unrestricted use as a result of the 1973 survey, and was used for storage, equipment maintenance, as a pistol firing range, and as a parking area by various government agencies and private organizations until the 1980s. A 1983 survey conducted by the Argonne National Laboratories (ANL) for the Department of Energy (DOE) revealed that residual radioactivity at the site exceeded regulatory levels established after the site's release. This survey reported DU concentrations in excess of the allowable levels in the burn area and in the field between the burn area and Buildings 234-236 (the clinker area), as well as some uranium tailings deposition in the area north of the burn area.

Chem-Nuclear Systems Inc. (CNSI) began remediation efforts in the burn area in 1989. This effort was to consist of removal, packaging, and disposal of soil and building rubble in areas found to have DU residue by ANL and by CNSI characterization surveys conducted in 1988. Areas which were identified as requiring remedial action included primarily the burn area, as well as other smaller and more isolated "hot spots." This work was halted after an oily sludge, which was found to contain DU, was unearthed during excavation of the burn area. CNSI then completed a comprehensive chemical and radiological survey of the site in 1990.

Harding ESE (then ABB Environmental Services [ABB-ES]) conducted a chemical characterization of the site under the Massachusetts Contingency Plan (MCP), and combined their results with a radiological characterization completed by Morrison Knudsen and Scientific Ecology Group, Inc. (MK/SEG) to produce a Human Health and Ecological Risk Assessment. Both HLA and MK/SEG completed their reports in 1996.

As a result of the information obtained from these surveys, the extent of chemical and radiological residues at the Site is at least partially characterized. Residual radioactivity associated with DU and uranium tailings is present at the site, in the burn area, portions of the clinker area, and part of the area north of the burn area. This radioactivity primarily affects the surface and subsurface soil, although contact does occur between DU and groundwater at the Site.

In addition to the radiological constituents, the site contains chemical contamination, with elevated levels of total recoverable petroleum hydrocarbons (TRPH), metals, and both volatile and semi-volatile organic compounds (VOCs and SVOCs). This contamination may be a result of activities at the site, but it is also likely that it is present as a result of upgradient activities, and as part of the fill material which was being added at the site through 1968. Chemical contamination is present in the surface and subsurface soil, groundwater, surface water, and marsh sediment at the site. The chemical contamination at the site is being addressed under the MCP by Harding ESE under contract to the Corps of Engineers.

Although significant areas of the Site have been shown to exhibit contamination, the areas located outside the perimeter fence are believed to be free of residual radioactivity, and to contain chemical contamination primarily related to upgradient activities.

DRAFT HISTORICAL SITE ASSESSMENT
GSA PROPERTY
WATERTOWN, MASSACHUSETTS

TABLE OF CONTENTS

DRAFT HISTORICAL SITE ASSESSMENT
GSA PROPERTY
WATERTOWN, MASSACHUSETTS

TABLE OF CONTENTS
(CONTINUED)

DRAFT HISTORICAL SITE ASSESSMENT
GSA PROPERTY
WATERTOWN, MASSACHUSETTS

TABLE OF CONTENTS
(CONTINUED)

DRAFT HISTORICAL SITE ASSESSMENT
GSA PROPERTY
WATERTOWN, MASSACHUSETTS

LIST OF FIGURES

DRAFT HISTORICAL SITE ASSESSMENT
GSA PROPERTY
WATERTOWN, MASSACHUSETTS

LIST OF APPENDICES

Glossary of Terms, Acronyms, and Abbreviations

ABB-ES	ABB Environmental Services
AEC	Atomic Energy Commission
AMMRC	Army Materials and Mechanics Research Center
AMTL	Army Materials Technology Laboratory
ANL	Argonne National Laboratory
ARL-WT	Army Research Laboratory
AST	Above-ground Storage Tank
ATF	Bureau of Alcohol, Tobacco, and Firearms
Bgs	below ground surface
COE	Army Corps of Engineers
CNSI	Chem-Nuclear Services Inc.
CRQL	contact required quantitation limits
cts/min	counts per minute
DCE	dichloroethene
DEA	Drug Enforcement Administration
DOE	Department of Energy
Dpm	Disintegrations per Minute
DU	Depleted Uranium
FBI	Federal Bureau of Investigation
FUDS	Formerly Utilized Defense Site
FUSRAP	Formerly Utilized Site Remedial Action Program
GM	Geiger Mueller Detector
GSA	General Services Administration
HLA	Harding Lawson Associates
HPGe	high purity germanium
HAS	Historical Site Assessment
ID	inside diameters
ISGS	in situ gamma spectrometry
IRS	Internal Revenue Service
MADEP	Massachusetts Department of Environmental Protection
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MC	methylene chloride
MCP	Massachusetts Contingency Plan
MDA	minimum detectable activity
MDC	Metropolitan District Commission

MED	Manhattan Engineer District
MEK	methyl ethyl ketone
MK/SEG	Morrison Knudsen and Scientific Ecology Group, Inc.
μμCi/100 cm^2	micro-nucro curries per 100 square centimeters. (Note: 1 μμCi = 2.2 dpm)
μR/hr	micro-Roentgens per hour
MSL	Mean Sea Level
MTBE	Methyl-t-butyl Ether
MTL	Materials Technology Laboratory
NED	Army Corps of Engineers, New England Division
NRC	Nuclear Regulatory Commission
NTU	nephelometric turbidity unit
OHM	Oil and Hazardous Material
PAH	polynuclear aromatic hydrocarbons
PAL	Public Archaeology Laboratory Inc.
PCE	tetrachloroethylene
pCi/g	pico Curies per gram
ppb	Parts per Billion
ppm	Parts per Million
PQL	practical quantitation limit
RCRA	Resource Conservation and Recovery Act
SVOC	Semi-Volatile Organic Compound
TAL	Target Analyte List
TCA	trichloroethane
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TOR	Top of Riser
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons
U+d	Uranium and Daughters
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UTM	universal transverse mercator
VOC	Volatile Organic Compound

1.0 PURPOSE OF THE HISTORICAL SITE ASSESSMENT

The primary contaminant of concern at the Site is DU, which was deposited at the Site as a result of its transportation to the burn area, and of the activities at the burn area. In addition, uranium ore and tailings are present in a small portion of the Site, likely generated by uranium ore research conducted by MIT and American Cyanamid at the Arsenal during the 1940s and early 1950s.

Since 1967, five separate investigations have been conducted to characterize the nature and extent of DU present at the site. Each was driven by the regulatory guidelines available at the time. In July 1997, the Nuclear Regulatory Commission (NRC) published new guidelines for assessing the potential radiological hazard from radioactive residues. These guidelines titled "Radiological Criteria for License Termination" were codified in 10 CFR parts 20, 30, 40, 50, 51, 70, and 72 and published in the Federal Register. This new regulatory driver requires the release of a site to be based on potential future dose rather than concentrations and necessitates the consideration of future use scenarios. In December 1997, the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) was released. This document was the result of cooperation between the U.S. Environmental Protection Agency (USEPA), the Nuclear Regulatory Commission (NRC), the DOE, and the Department of Defense (DOD). MARSSIM provides a nationally consistent consensus approach to conducting radiation surveys and investigations at potentially contaminated sites involving radioactivity.

This Historical Site Assessment (HSA) has been prepared consistent with MARSSIM guidance. The HSA has collected all available existing information on the GSA Property, and describes the Site's radiological history from the start of Site activities to the present time. This document is based primarily on radiological data and reports prepared by others; Harding ESE has not collected any additional site data during the preparation of this HSA. All reported observations and conclusions are those included in the documents that have been reviewed and, except where noted, do not reflect any additional interpretation by Harding ESE. Harding ESE comments have been included as italicized text.

Under a related effort, site-specific release criteria will be developed for various plausible re-use scenarios for the GSA Property. The HSA will be used to determine the suitability of existing site characterization data to support the site-specific release criteria, and to identify data gaps.

2.0 PROPERTY IDENTIFICATION

2.1 PHYSICAL CHARACTERISTICS

2.1.1 Name

The area which will be referred to as the Site is more formally known as the GSA Property and Property 20 of the Watertown Arsenal. During the period of active Site use (until about 1967) it was called the Northeast Area of the Arsenal. After the transfer of the Site to GSA control, it was known as the Federal Property Resources Center. It is currently owned by the GSA (General Services Administration), with the Army Corps of Engineers (COE) maintaining responsibility for the disposition of radioactive material on the Site. Contact information for the GSA and COE follows:

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In 1990, the Massachusetts Department of Environmental Protection (MADEP) listed the site under tracking number 3-02722 as the GSA Federal Property Resources Center. The Site was originally classified as a Location to be Investigated (LTBI), but was subsequently classified as a Priority Disposal Site in 1992 as a result of the residual radioactivity, mixed chemical and radiological materials, proximity to the Charles River, the presence of Sawins Pond Brook along the property margin, and the high water table. In 1993 the Massachusetts Contingency Plan (MCP) was revised, and in 1994 MADEP reclassified the Site as a Tier IA site. Response actions at Tier IA sites are subject to direct MADEP oversight and approvals.

The GSA does not have an NRC license for the DU which is present on the property. However, most of the radioactive material at the Site was generated at the Army Material Technology Laboratories under their license SUB-238.

2.1.2 Location

The Site is located at 670 Arsenal Street in the eastern portion of the Town of Watertown, Massachusetts. It is in Middlesex County, at 42º21'40" N latitude and 71º08'50" W longitude. The UTM Coordinates are 4692150mN and 0323000mE. Figure 2-1 shows the Site location.

2.1.3 Topography & Site Description

The Site falls on the Newton, MA 7.5 minute quadrangle, 1970. Site topography is essentially flat, and was formerly part of the floodplain of the Charles River. The floodplain formerly located at the Site was filled during the 1940s, and the present land surface lies at approximately 6 to 8 feet above mean sea level (MSL). Elevations in the area of the GSA Property range from 1 foot above MSL along the banks of the Charles River to 40 to 45 feet above MSL along parts of Coolidge Street to the west (ABB-ES, 1996).

Most of the property is surrounded by an 8 foot tall chain link fence topped with barbed wire, which is broken by five different gates, all padlocked. The fence was extended in 1994 to enclose the northeastern portion of the GSA Property and a portion of Property 20. Buildings 234 through 236 are contained in a smaller fenced enclosure, which is paved, at the southern end of the Site. Building 653, Sawins Pond Brook on the south edge of the Site, and wetlands and vegetated areas located along the northwest property boundary are located on-site outside of the chain link fence. Figure 2-2 shows the Site structures, utilities, and wetlands.

An entrance driveway provides access to the Site from Arsenal Street onto the southern portion of the Site. This area is paved with bituminous concrete, and contains four buildings. Building 653 was a pumphouse which supplied water to the Site and/or pumped sanitary sewage wastewater to the sewer main under Arsenal Street. It lies along the access road. Buildings 234 and 235 are one story concrete block and brick buildings set on concrete slabs, constructed for supply storage They are approximately 60 feet by 275 feet, and were built by 1952, with an annex on the northeastern side of Building 235 measuring approximately 30 feet by 75 feet which is listed as being in use in 1963 (PAL); this annex appears to be present in an aerial photo from 1952. Building 236 is a corrugated steel building set on a concrete slab, measuring approximately 40 feet by 100 feet. According to Public Archaeology Laboratory, Inc. (PAL), it was constructed in 1951. Building 237 is a shed located in what is known as the clinker area, approximately 10 feet by 30 feet in dimension. The rest of the property is unpaved, although vestiges of asphalt pavement are visible north of Building 235 in the clinker area. In the northern third of the GSA Property is the burn pit, the area formerly used for the burning of DU; it now consists of a round hole, approximately 25 to 30 feet in diameter, filled with water. Several additional areas within the security fence are marked off by radiation hazard ropes based on the results of MK/SEG's investigations in 1994 and 1995.

The Site is connected to the municipal water and sanitary sewer systems, although these systems could not likely be made operational. The sanitary sewer service connects from beneath Arsenal Street to Building 235, and includes pumphouse Building 653. No water supply wells, septic tanks, or leachfields are located at the Site. One water main serves the facility and enters the property from Arsenal Street. It is located along the western fence line. The water main provided

drinking and fire protection service water to Buildings 234 and 235 and extends along the western edge of the property to a hydrant located northwest of the burn pit area. The water main has reportedly been capped at a hydrant located behind Building 236 (ABB-ES, 1993).

The facility has aboveground and underground electrical and telephone connections. Electric power enters the property from Arsenal Street, and crosses Sawins Pond Brook to a pole-mounted transformer located within the fenced building enclosure. Electricity is then distributed to the buildings via underground cables and subsequently distributed to pole-mounted light fixtures located at regular intervals along the perimeter fence.

Natural gas lines enter Building 235 from Arsenal Street at the southeast corner of the building. The buildings are currently not heated but can be heated by a natural gas-fired boiler located in Building 235.

A storm water catch basin is located near the Arsenal Street entrance to the GSA Property. This storm drain discharges to Sawins Pond Brook via a vitrified clay pipe. A second storm water catch basin is located northeast of Building 235 near the edge of the asphalt area. A third catch basin is located between Greenough Boulevard and the security fence approximately 150 feet north of the second basin, and receives surface runoff from the GSA Property (Figure 2-2). A culvert apparently connects this catchbasin with a headwall and discharge pipe located east of Greenough Boulevard. Water discharging from this headwall structure flows southeast along a drainage channel to a discharge point at the Charles River, (Utility summary from ABB-ES 1996).

2.1.4 Storage Tanks

A 1,000-gallon fuel oil underground storage tank (UST) was formerly located adjacent to Building 235. The tank was used to store No. 2 heating oil. The tank was at least 20 years old when it was removed by contractors engaged by the COE in the summer of 1993 as part of a MADEP-approved Interim Measure conducted at the Site. According to Dr. Ian Osgerby, the Interim Engineering Manager for the GSA Property at that time, petroleum contamination was observed around the tank fill pipe, and a petroleum odor was noted in the tank excavation (ABB-ES, 1993).

An empty holding cradle for an above-ground storage tank (AST) is present adjacent to the north side of Building 235. A 1,000-gallon heating oil tank was located in this cradle until approximately 1991, when the tank was removed. GSA personnel had observed that oil was seeping from the tank piping fixtures, but did not remember any leaks or spills associated with the tank (Storage tank summary from ABB-ES, 1993).

Between September 1992 and December 1994, wetland delineation was performed at the GSA Property by COE ecologists and biologists. This delineation identified various wetland areas on the Site. The initial wetland report indicated that the wetlands at the GSA Property have a very low relative value due to the disturbed site conditions and the proximity of the wetlands to Greenough Boulevard. The 150 foot wetlands buffer zone (Figure 2-2) extends to the west such that it crosses the center of the Site in an approximately northeast to southwest line (ABB-ES, 1996).

The areas which lie outside the perimeter fences are generally termed the boundary areas. These include the wetland adjacent to the western fence-line and the grass strip between the eastern fence-line and Greenough Boulevard. Property 20 refers to the parcel at the northern edge of the Site which is owned by the Metropolitan District Commission (MDC). In 1994, the perimeter fence was extended to enclose a portion of Property 20, following the discovery of uranium ore and tailings. The burn area, or burn pit area, refers to the area containing the concrete pad on which the Arsenal burned DU scrap, which has since been excavated by successive remedial efforts to form a round hole, approximately 25 to 30 feet in diameter, filled with water. The area enclosed by the security fence to the south of the burn area is referred to as the clinker area due to the quantity of clinker material on the surface and in the fill used in this portion of the property. The final area of the Site is the paved area surrounding Buildings 234 and 235.

2.1.5 Stratigraphy

The Middlesex County Interim Soil Survey report, completed in July of 1986 by the U.S. Department of Agriculture Soil Conservation Survey and referenced in CNSI 1990, classifies the surface and near-surface soils as excavated or deposited due to construction operations, a description which corresponds to the filling of the property during the 1940s. Unconsolidated soils encountered during soil borings at the Site during the CNSI comprehensive site assessment (CNSI, 1990) consisted of a downward stratigraphic sequence of artificial fill, organic silt and peat, and stratified sands (Figures 2-3 through 1-6 illustrate the stratigraphy of the site). The artificial fill ranged from 4 to 12.5 feet in thickness and consisted of a black-to-brown, loose-to-compact mixture of sand, gravel, and silt with varying amounts of fire brick and other debris.

The soil directly under the fill consisted of a mixture of organic silt and peat. The color was typically greenish gray to brown or dark gray and contained varying amounts of fibers, roots, and other vegetative matter. The peat represents the swampy marsh associated with the Charles River which occupied the GSA Property prior to filling and development. The peat layer was observed to be 2.5 feet to more than 12.5 feet thick. Cross sections show the variability of the peat layer throughout the site, which is consistent with its origin as marsh sediments; it indicates an area formerly characterized by small islands and channels. Borings conducted by others at Coolidge Street indicate the peat is discontinuous beneath the higher ground to the west (ABB-ES, 1996).

A semi-stratified sand and gravel deposit was observed below the peat layer in deeper borings and likely represents glacial outwash. The total thickness of this layer was not established, and the deepest penetration below ground surface was 51 feet. Bedrock or till deposits were not encountered during CNSI subsurface investigations. The bedrock that underlies this part of Watertown has been mapped as the Cambridge Argillite. Broken rock possibly signaling the bedrock surface was encountered at 93 feet below grade surface (bgs) during the 1959 installation of a water production well at the Watertown Arsenal (ABB-ES, 1996).

2.2 ENVIRONMENTAL SETTING

2.2.1 Geology

The soil boring and sampling programs conducted by CNSI in 1990, MK/SEG in 1993-4 and HLA in 1994 have provided information about the site soil stratigraphy. In general a downward stratigraphic sequence is artificial fill, organic clay/peat, and sands (ABB-ES, 1996).

Artificial Fill
The artificial fill ranges in thickness from 4 to 14 feet. It consists of brown to black, loose to medium dense sand, gravel, and silt with varying amounts of fire brick, slag, and coal with occasional pieces of wood and metal (ABB-ES, 1996).

The bricks, slag, and metal encountered at the Site are detailed below:

- pale yellow bricks commonly referred to as fire bricks because of their presumed use as insulating bricks in ovens, kilns, and heat treatment facilities; fire bricks and brick fragments were visible in the area of the burn pit excavation and were common in many of the borings.

- boiler slag (clinkers) or bottom ash; this vesicular siliceous material was visible at the surface or in surface soil samples collected in most unpaved areas of the property. Boiler slag typically contains large percentages of silica and iron and aluminum oxides with trace concentrations of other elements.

- metal debris, steel cables, and irregular metal castings were observed at various locations around the Site and in some of the subsurface soil samples (ABB-ES, 1996).

Peat
The soil directly under the fill consists of organic peat representing the swampy marsh that occupied the GSA Property prior to filling and development of this section of the Charles River floodplain. The color is typically brown to gray and contained varying amounts of fibers, and roots. The peat ranges in thickness from 2.5 feet to 12.5 feet. The peat layer is continuous throughout the GSA Property. CNSI (1990) and MK/SEG (1993-1994) encountered the peat layer in all of their borings. Harding ESE (1994) encountered the peat layer in all but eight borings, and the absence of the peat layer in these borings may be explained by the fact that continuous samples were not collected at all locations during the 1994 Harding ESE field investigation. Borings conducted by others in the Coolidge Street area north and west of the GSA Property indicate that the peat layer is discontinuous beneath the higher ground to the west (ABB-ES, 1996).

Stratified Sands
According to CNSI (1990) boring logs, a semi-stratified sand and gravel deposit was observed below the peat layer in deeper borings and likely represents glacial outwash. The sand below the peat ranged from well-sorted medium to fine sands to poorly sorted gravelly sands with varying amounts of fines throughout the layer. The total thickness of the sand layer was not established because no boring penetrated below the sand layer. The sand layer was encountered beginning at

approximately 11 to 15 feet bgs, and continuous to the bottom of the four deepest borings at 51 feet bgs (ABB-ES, 1996).

Bedrock
Neither bedrock nor glacial till was encountered during the CNSI (1990), MK/SEG (1993-1994), and Harding ESE (1994) boring programs. According to the Remedial Investigation (RI) Report (Weston, 1992) prepared for the nearby Army Research Laboratory (ARL-WT), the depth to bedrock in this area of Watertown ranges from approximately 50-100 feet bgs. The underlying bedrock in this part of Watertown has been mapped as the Cambridge Argillite (ABB-ES, 1996).

2.2.2 Hydrogeology

This assessment of site hydrogeology is based on data and observations recorded during field investigations conducted by Harding ESE and CNSI. Harding ESE's field activities included hydraulic conductivity testing (slug testing) in five groundwater monitoring wells and a comprehensive round of water level measurements. Water levels were measured in the five newly installed wells and 14 monitoring wells previously installed by CNSI.

The Site was historically wetland associated with the Charles River floodplain. Portions of the Site remain wetland areas, and several surface water bodies, including Sawins Pond Brook and the Charles River, currently exist on or near the property. Sawins Pond Brook flows along the southern site boundary. The Charles River flows eastward to the south of the Site, then bends northward at approximately 400 feet southeast of the Site and flows parallel to Greenough Boulevard and the eastern site boundary (Figure 2-1).

Depths to groundwater measured by HLA on November 17, 1994 ranged from 2.01 to 7.19 feet below the top of the PVC well risers (TOR) across the Site. The water table elevation ranged from 5.21 to 6.85 feet above mean sea level. Shallow groundwater beneath the Site generally flowed to the east and southeast through a coarse, rubble fill underlain by a clay and peat layer that likely impedes vertical flow of groundwater (and associated contaminants). Groundwater elevation contours based on measurements from November of 1994 are shown on Figure 2-7.

The peat layer is very fine grained, and represents a hydrologic barrier between the fill above and the sand below. In addition, this layer should chemically adsorb organic molecules, restricting their movement through the peat. The underlying stratified sand unit is confined by the peat layer, resulting in piezometric levels in the lower aquifer that were 0.4 to 1.5 feet higher in the northern section of the Site than those of the upper aquifer. The head of the lower aquifer is approximately 0.7 feet lower than that of the upper aquifer in the southern sector, however (CNSI, 1990).

In 1994, HLA found the horizontal hydraulic gradient to be essentially flat (0.0001 ft/ft) at the north end of the Site. Groundwater in this area eventually either flows eastward and discharges to the Charles River or flows southeastward toward the southern portion of the Site. There is also likely a northward component discharging into the wetland area north of the Site. The gradient increased dramatically at the center of the Site to 0.007 ft/ft, then appears to flatten out again to

0.0001 ft/ft at the south end. Groundwater from the south end of the Site discharges toward Sawins Pond Brook and the Charles River.

Hydraulic conductivities were measured in five wells using slug test techniques. The conductivity values ranged from 41.4 feet per day to 2,040 feet per day. All of the wells were screened at least partially through the coarse fill material and exhibited rapid recharge rates. The conductivities calculated for the five HLA wells are consistent with the values calculated for the CNSI wells in the same vicinity. The CNSI wells installed at the southern area of the Site exhibited markedly lower hydraulic conductivities than those in the northern area, near the HLA wells. The hydraulic conductivity of the lower, stratified sand unit was more uniform. It ranged from 1.9 to 34.5 feet per day, and averaged 15.6 feet per day (CNSI, 1990).

The groundwater flow velocity in the northern Site area, where the water table is flat, was calculated to be approximately 0.23 ft/day, using a gradient of 0.0001 ft/ft and data from MW-101 through MW-104. The groundwater flow velocity in the northeastern portion of the Site, calculated using an assumed gradient of 0.004 ft/ft (site average value), is approximately 13 ft/day to the north and east. Calculations performed using data from the CNSI investigation indicate that the groundwater flow velocity in the southern Site area ranges from 0.004 ft./day to 6.3 ft/day toward the Charles River and Sawins Pond Brook (ABB-ES, 1996).

2.2.3 Hydrology

The hydrology of the Site has been heavily altered by human activity. In addition to the emplacement of fill over the peat layer, which functions as an aquitard, producing a perched water table, the original drainage pattern of the Site has been altered. A small stream once flowed across the middle of the Site; this stream was filled in the early part of the century. Around the same time, the stream which drains Sawins Pond was rerouted to its current path along the southern boundary of the Site. The flooding problems which the pond created led to the construction of additional outlets and culverts in the 1960s (CNSI, 1990).

Wetlands, although of low value due to the disturbed nature of the Site and the presence of Greenough Boulevard, cover a significant portion of the Site. A pond lies along part of the western site boundary, and another pond exists in the northeastern portion of Property 20. The area along the eastern perimeter is marshy, as is a large section of the Site north and east of the burn area. The 150 foot wetland buffer zone divides the Site approximately in half northeast to southwest.

The presence of peat deposits below the fill materials and the history of the property as part of the Charles River floodplain have resulted in high water table conditions at the Site This condition is further caused by the presence of a retaining wall to the west, from which a constant seepage of groundwater flows, as well as by the emplacement of compacted earth materials during the construction of Greenough Boulevard. During wet seasons, the high water table is expressed as areas of flooding on the property. During heavy rainfall or after flooding, surface water runoff drains to a swale along Greenough Boulevard, to the wetlands area adjacent to Grove Street to the north, to the wetlands at the base of the retaining wall along the western side of the property, and

to Sawins Pond Brook at the southern margin of the property (ABB-ES, 1996). All surface water from the Site eventually flows to the Charles River, approximately 150 feet east of the Site.

Runoff varies across the Site. Precipitation runoff is greatest in the southern, paved portion of the Site. Greatest recharge to the ground water table is expected in the central part of the Site, where there is less vegetation, and the surface layer is gravelly. Slightly less recharge would be expected in the heavily vegetated northern portions of the site due to evapotranspiration (CNSI 1990).

Flooding is common at the Site. Both overflow from Sawins Pond Brook and field saturation of the soil play a part in the frequent flood events. Even during drier periods, the water table lies either at or within a few feet of the ground surface, limiting storage capacity of the soils (CNSI, 1990).

2.2.4 Meteorology

The climate in the area is influenced by prevailing westerlies. The prevailing wind is from the northwest in the fall and winter, and from the southwest in spring and summer. The average wind speed in Boston is about 12 mph (CNSI, 1990).

Watertown is located in what is termed the "coastal division climate" designation for Massachusetts. The average annual temperature is about 51º F near Boston as measured at the airport. The highest monthly average temperatures are in the low 70's for the coastal division in July. The lowest monthly average temperatures are in the 30's, and occur in January (CNSI, 1990).

Average monthly precipitation amounts are distributed evenly throughout the year, although precipitation intensities are sometimes greater in summer months due to occasional thunderstorms. The average annual precipitation for Boston from 1941 to 1980 was 42.52 inches per year. About 20 inches of this precipitation is estimated to runoff in typical urban areas around Boston. Boston receives about 30 inches of snowfall each year (CNSI, 1990).

3.0 HISTORICAL SITE ASSESSMENT METHODOLOGY

3.1 APPROACH AND RATIONALE

This Historical Site Assessment is intended to provide a summary of previous investigations completed at the Site, in addition to assembling a history of the Site's use from the active period of the Watertown Arsenal to the present. To this end, the reports compiled before and after survey and remediation work was completed by ANL, CNSI, HLA, and MK/SEG were consulted, as was a collection of documents pertaining to earlier survey and remediation efforts completed by the Army. Chemical data has been included because of the potential that any material with residual radioactivity which might require removal might also contain chemicals of concern.

Harding ESE commentary associated with the findings or conclusions of others is included as italicized text.

3.2 BOUNDARIES OF SITE

The Site is considered to be the 11.91 acre GSA Property, as well as the much smaller MDC-owned Property 20 which adjoins the GSA Property to the northeast. The total area of the Site is approximately 12 acres (ABB-ES, 1996). The Site is bounded on the north by Grove Street, on the east by Greenough Boulevard, on the South by Arsenal Street, and on the west by privately held properties facing on Coolidge Avenue.

3.3 DOCUMENTS REVIEWED

A number of sources were consulted regarding the history of this site. They are as follows:

- A collection of documents pertaining to the Site assembled in 1993 by John Kinneman of the NRC (Nuclear Regulatory Commission) from the files of the MTL (Materials Technology Laboratory), the NED (New England Division of the Corps of Engineers), and the NRC.
- A summary of the history of the Arsenal site as a whole, based on an archival review completed in 1992 by The Public Archaeology Laboratory Inc. (PAL).
- Draft Supplemental Phase II Comprehensive Site Assessment, prepared by ABB-ES in 1996.
- Radiological Characterization and Final Survey Report, compiled by Scientific Ecology Group, Inc. (SEG) and Morrison Knudsen (MK) in 1996.
- Preliminary Assessment of the Former Watertown Arsenal, completed by ABB-ES in 1993.
- Comprehensive Site Assessment of the GSA Federal Property Resources Center, prepared by CNSI (Chem-Nuclear Systems, Inc.) and O'Brien and Gere Engineers, Inc. in 1990.
- Radiological Survey of the Former Watertown Arsenal Property GSA Site, completed in 1983 by Argonne National Laboratories (ANL).
- Army Materials Technology Laboratory Facility Decommissioning Plan, prepared by Roy F. Weston Inc. in 1992.

3.4 PROPERTY INSPECTIONS

No site inspections were specifically conducted to support this HSA. Site conditions described in this document are based on observations reported by others while conducting the various characterization and remediation efforts at the site.

The site is periodically inspected by NRC, the COE, and/or Harding ESE. The purpose of these inspections is to check the security of the property from trespassers and to gather information and measure compliance with NRC regulations and license conditions. Warning signs have been placed on four gates to the secured area; two on the southern fenceline, and two on the eastern fence line along Greenough Boulevard. The warning signs are intended to prevent trespassing and provide the public with a COE point of contact to answer site-specific concerns.

Most of the GSA Property is currently heavily vegetated with vines, brush, and small trees. Any additional site work that may be necessary will likely require substantial clearing to provide access.

3.5 PERSONNEL INTERVIEWS

Interviews were conducted as part of the previous investigations, and were referenced when necessary during the preparation of this document. No new interviews were conducted in the preparation of this Historical Site Assessment.

4.0 HISTORY AND CURRENT USAGE

Information concerning the history and current usage of the GSA site was gathered from summaries in several of the sources mentioned in section 2.3. The primary source for the site information used in this report is the ABB-ES Draft Supplemental Phase II Comprehensive Site Assessment, with some clarifications from other sources where descriptions are incomplete or vary from earlier reference works.

4.1 HISTORY

Much of the history of active use of the Site is not well documented, with many dates either unavailable or conflicting in different sources. The 11.91 acres which comprise the GSA site were transferred to the United States for the use of the Department of the Army by the Commonwealth of Massachusetts with a quitclaim deed in March of 1920 (ABB-ES, 1993), and Property 20 was leased to the Army in June of 1948 (CNSI, 1990). The deed for the GSA Property is subject to a reverter clause, which stipulates that if the Army should no longer need the property, ownership reverts back to the Commonwealth. The property was transferred to GSA control in August of 1968 with the stipulation that the responsibility for all remaining radiological contamination remained with the Army (ABB-ES, 1993). The stipulation that the U.S. Army retains responsibility was identified in an agreement between the Army and GSA. The NRC has since indicated that GSA, as new owners of the property, can be held responsible for cleanup. In October of 1984 the Commonwealth filed a "Notice of Right-of-Entry for Condition Broken or Possibility of Reverter" for the GSA Property, with the intention that the Site will revert to state control.

A 1938 aerial photograph (Appendix A) indicates that the Site was primarily undeveloped vegetated land. An unpaved road appears to lead from Arsenal Street into the property along the western property boundary. Portions of this road are still visible along the western edge of the property.

The buildings on-site were built shortly after World War II. The PAL archival review indicates that Buildings 234 and 235 were built between 1946 and 1952, and an aerial photograph from 1951 shows Buildings 234 and 235 as well as 653. Building 236 was built during 1951 according to PAL, and is visible in the 1952 aerial photograph. During the 1950s a tower was constructed in the clinker area to the north of Building 235. Its use is unclear, and it was later dismantled. Exact dates for the erection and removal of the tower are not available. A lean-to on Building 235 is listed as being in use in 1963 (PAL); this lean-to appears to be present in an aerial photo from 1952. The date of construction of Building 237 was not discussed in any of the documents reviewed. Building 237 first appears on an aerial photograph from 1969 (Appendix A). Figure 4-1 shows the site during its period of active use.

MIT and American Cyanamid conducted uranium ores testing at the Arsenal from 1946 through 1953. A modified ion exchange technique for production of U_3O_8, which employed a fluidized bed system, was developed at this site (DOE, 1980). The waste products from this testing consisted of uranium daughter products (ABB-ES, 1993). Some tailings generated by this activity were apparently disposed of at the northern end of the Site and on Property 20 between 1948 and 1951 (NRC Technical Evaluation Report, April 2000). MK/SEG determined that

elevated radiation levels due to tailings material were present at one location in Property 20 based on the presence of radium 226 and not thorium 234.

An area in the northern portion of the GSA Property was designated for the burning of DU turnings and DU waste generated by machining and melting operations at the Arsenal. The melting operations included the use of thorium crucibles, but these crucibles were apparently not brought to the Northeast Area, but instead disposed of as radioactive waste Appendix B-18). The Arsenal began processing DU during the 1950s, and most sources describe this use as having begun in the mid-1950s, although there is not complete agreement. The Draft Phase II Comprehensive Site Assessment (ABB-ES, 1993) and MK/SEG (1996) both list the date of commencement of these activities as having been approximately 1955. However, the NRC describes the use of the Site for the packaging and storing of radioactive waste, burning of uranium scrap, and staging of radioactive waste shipments from the 1940s until the 1960s in a history compiled in 1993 (This history and several attachments are included as Appendix B). In an Arsenal letter dated December 22, 1966, it is stated that uranium chips had been burned at the Northeast Area for approximately 7 years, placing the start of DU incineration in approximately 1959(Appendix B-2).

The burn area is not visible in an aerial photo taken in 1951, and it is not likely visible in a similar photo from 1952. For this reason, it seems likely that the DU burning operations did not in fact begin until the mid-to late1950s.

The machining operations performed with DU at the Arsenal included grinding, milling, heat treating and melting, cutting, drilling, electrochemical plating, and polishing. Additionally, the Arsenal undertook ballistics testing and chemical research. The DU scrap was stored in barrels packed with cooling oil to prevent exposure to the air, since small particles of DU are pyrophoric. PAL describes the process of DU waste disposal as follows:

> "The barrels of scrap are dumped into large steel vats, and when enough has accumulated, the scrap is ignited and allowed to burn out. The smoke is monitored downstream. While some contamination is experienced, the area is such that it can be covered by use of a bulldozer and rendered innocuous; the soil already contains 0.0001 percent uranium, and the amount added by the burning operation increases this only modestly. When the container is full of oxide, a top is welded on and the whole is shipped to a commercial burial site contracted for by Edgewood Arsenal. The burning area is provided with a concrete pad and a wire fence enclosure is kept locked (PAL, 1992)."

The 1990 CNSI report hypothesizes several additional elements of the burning process. They suggest that wood or wood products and igniting fluids may have been used in the burn area to enhance the burning process. CNSI encountered a black tarry sludge beneath a concrete structure which they describe as a monolith approximately 8 feet beneath the surface of the burn area during their excavation activities in 1989. This sludge contained polynuclear aromatic hydrocarbon (PAH) residues, which may have been produced by the incomplete combustion of wood materials or other fuels. In addition, trace amounts of chlorinated solvents were detected, indicating the possible disposal of solvents in the burn area (CNSI, 1990).

The physical arrangement of the burn area remains somewhat unclear. Other sources describe the burning of the DU as having taken place on the concrete pad, but CNSI suggests another arrangement in their description of the area as they found it in their 1990 report. The surface concrete pad was 18 feet by 29 feet, and approximately 1 to 1½ inches thick. A large concrete monolith was encountered roughly one foot beneath the surface. The monolith was 6 feet thick, and measured 4 feet by 4 feet at its top, and 5 feet by 5 feet at its bottom. It was located immediately northwest of the surface pad. In addition, a smooth surface was encountered at 8 to 9 feet below grade, beneath the monolith. CNSI interprets this surface as a concrete structure. CNSI suggests that these structures may have been part of an old foundation or support structure which was converted for the burning of DU. They estimate the total area of the burn pit at least 522 feet², and assume that the burning of DU took place mainly beneath the concrete monolith, at approximately 8 feet bgs.

This theory is not supported by aerial photos or any other reference. However, there is no explanation for the presence of the monolith or the smooth surface (which Morrison Knudsen later determined to be a layer of larger fill material). It seems likely that these objects were simply waste materials which were placed on the site as fill, and were originally used at some other portion of the Arsenal. It is virtually certain that the DU chips were burned in dumpsters on the concrete pad.

Shipments of DU for disposal which originated at the Arsenal are listed. Solid wastes were sent to Crossroads Marine Disposal Corporation in 1958, 1960, five times in 1961, and three times in 1962. These dumpsters and drums probably contained DU from the burn pit (ABB-ES, 1993). A letter docketed in 1966 describes the dumpsters which were used to contain the waste generated by the burning operation. The chips were incinerated in specially constructed dumpsters made of ½ inch steel plate, which were 3½ feet wide by 6 feet long by 3½ feet deep (Appendix B-3). A switch from Marine Disposal to land burial was made in 1963, and the final disposition of DU appears to have taken place in 1967 (ABB-ES, 1993). The Site was used as a fill site for rubble and debris from the operations at the Arsenal property through 1968 (MK/SEG, 1996).

Several efforts at characterization and cleanup of the DU contamination have been made. In 1966, the Army undertook a radiological survey and decontamination program. The Army Materials and Mechanics Research Center (AMMRC) performed a radiological survey of the Site in preparation for the transfer of the property to the GSA in 1967. The property transfer to GSA took place in August of 1968, with the AMMRC maintaining responsibility for the property until decontamination was complete. In October 1973, a further study and decontamination effort was carried out by the AMMRC with the intention of releasing the Site for unrestricted use by the GSA. The survey found no loose contamination, and standards had not yet been established for acceptable levels of uranium contamination in soils. The Atomic Energy Commission (AEC) released the Site for unrestricted use in January of 1974 based on the results of the AMMRC radiation survey from October of 1973.

The Site began to be used by GSA and other agencies and private organizations. By 1981, the GSA; the U.S. Customs Service; the Bureau of Alcohol, Tobacco, and Firearms (ATF); the Internal Revenue Service (IRS); and the Drug Enforcement Administration (DEA) were all using the Site. The buildings were being used for storage, equipment maintenance, and a pistol firing range. An outdoor fenced area (the clinker area) was being used for storage of excess federal

vehicles pending disposal at auctions, some of which were also conducted at the property. In addition, the Federal Bureau of Investigation (FBI) used the Site as a Motor Pool, changing oil, repairing radios, and performing other related work. The DEA stored vehicles in one of the buildings, and the GSA and IRS stored miscellaneous materials such as lights, partitions, and bulk paper supplies (NRC File Report, 1993, and CNSI, 1990).

The GSA also leased parts of the Site for use by private organizations. The clinker area was leased to Oste Chevrolet and Peter Fuller from 1985 to 1988 for the storage of motor vehicles and mechanical work, and Building 237 was used for tire storage. Building 236 was leased to the television production company Spencer for Hire from 1986 to 1988. A pistol range was housed in Building 235 (CNSI, 1990), and decontaminated of lead in 1989 by Dennison Oil, under contract to GSA.

In 1981 ANL performed a radiological survey under the DOE Formerly Utilized Site Remedial Action Program (FUSRAP), because documentation of previous decontamination procedures from 1973 which led to the 1974 release of the property for unrestricted use were insufficient to meet more recent NRC standards. At the time of the survey, there were no regulatory standards for allowable soil concentrations of residual radioactivity, and so the decontamination efforts worked to achieve standards which were written by Sidney Levin, the director of the project, and approved by the AEC. It was determined that residual radioactivity concentrations at the Site exceeded acceptable limits, but also that the DOE could not conduct a remedial action under the FUSRAP. In 1986, the GSA requested guidance from the NRC for the sale of the property. The NRC responded that the concentrations of source materials in the soil exceeded limits for unrestricted use of the property, and indicated two necessary actions: Application for an NRC license to cover possession of the contaminated property, and submission of a decontamination disposal plan outlining the anticipated future use of the property and providing a timetable for bringing the Site into compliance. Further discussion with the NRC indicated the GSA's intention of hiring a consultant to fulfill the NRC requirements for the Site.

CNSI performed a survey of residual radioactive materials, primarily in the burn pit area, and then removed, packaged, and disposed of soil and building rubble contaminated with DU in 1988 to 1989. Remediation work in the burn area was halted when an oily sludge was uncovered during the excavation. In 1990, CNSI completed a Comprehensive Site Assessment under the MCP. MK/SEG undertook a remediation project on the burn pit in 1993, but work was halted because of the risk of spreading contamination. Environmental and radiological surveys followed the halt in work in 1993 and 1994. HLA completed an environmental investigation sampling program in 1994, as well as test trenching and drum removal in 1996.

The surveys are discussed in detail in section 5.

4.2 CURRENT USAGE

The Site is not currently in use. The paved area surrounding Buildings 234 and 235, which is outside the secured area of the Site, has been leased to a paving contractor for the storage of heavy equipment and raw materials. The tenant does not have access to any of the buildings, or to the secured areas. The remainder of the Site is heavily overgrown and not easily accessible. Within the perimeter fence, there are four areas which are cordoned off due to radiation hazards.

Some of these barriers have been knocked over or damaged by weathering and may require replacement and regular maintenance until disposition of the site is decided.

4.3 ADJACENT LAND USAGE

The properties abutting the GSA site are a mixture of recreational, residential, light industrial, and commercial areas. The area west of the Site is zoned for heavy industry, the area to the north is zoned residential, and to the east and the southeast the classification is open space conservancy. Upgradient properties along Coolidge Avenue contain light industrial and commercial uses, as well as two condominium complexes, a parking lot, and tennis courts. The area to the east of the Site contains recreational pedestrian paths and open and wetland areas (CNSI, 1990). The Site and its immediate area are shown in Figure 4-2.

There is the potential that some chemical contamination at the GSA site (particularly in groundwater and Sawins Pond Brook sediments) could be due to upgradient sources. A number of potential sources for contaminants exist or have existed historically in the area surrounding the property since Watertown's settlement.

Hood Rubber Company established a factory to the west of the Site, and several portions of the former Hood property are now sites of environmental concern. The Watertown Dump was also located nearby, in former sand and gravel pits (CNSI, 1990).

As of 1992, MADEP had listed 12 locations within one-half mile of the Site. The following is a short summary of potentially pertinent sites and spills (ABB-ES, 1993):

- MADEP Site No. 3-3539. A manufacturer of electric motors. Operations included resin coating, varnishing and soldering. Documented contamination of the groundwater includes 1,1,1-trichloroethane (1,1,1-TCA) and tetrachloroethylene (PCE) up to 55,000 µg/L. Surface soil at the site contained total petroleum hydrocarbons (TPH) levels ranging up to 102,000 parts per million (ppm).
- MADEP Site No. 3-1535. A metal fabricating, engraving, stamping, and silk-screening site. Contaminants detected in the groundwater at this site include toluene, 2-hexanone, trichloroethene (TCE), and 1,1-DCA. TCE concentrations ranged up to 4,100 µg/L.
- MADEP Site No. 3-1410. A former gas station to the west of the site. Six USTs were identified and removed, and oil contaminated soils were stockpiled. No separate liquid phase petroleum product was reported on the water table. The status of 5 additional reported USTs was unknown at the time of the draft Phase II report (ABB-ES, 1993). Oil spillage from the station had been observed on Arsenal Street entering catch basins, and discharging to the Charles River. Also, gasoline contaminated soil was reportedly used as backfill following UST removal operations (ABB-ES, 1993).
- MADEP Site No. 3-1910. A property at which 1,1,1-TCA, TCE, and PCE had been detected on-site. The report detailing the site assessment activities was not included in the MADEP file, and the contaminated media and concentrations were unavailable (ABB-ES, 1993).
- MADEP Site No. 3-1887. An industrial property which was at one point used for solvent storage. Subsurface investigations performed in 1988 indicated the presence of oil, grease, and chlorinated VOCs in both soil and groundwater. VOCs included carbon tetrachloride, PCE, and TCE.

- MADEP Site No. 3-0514. A second service station, from which two USTs were removed in 1987. During removal, gasoline contaminated soils extending to the water table were reported. Free petroleum products were also observed on the groundwater. Gasoline-contamination of soils was confirmed, but chlorinated hydrocarbons were not detected.
- MADEP Site No. 3-0457. Sawins and Williams Ponds were part of the Hood Rubber property and may once have been used for the disposal of rubber products and spent solvents. In addition, the ponds receive drainage from municipal storm sewers. Sediment contamination includes mercury, arsenic, and lead. PCBs have also been detected at up to 11 ppm. TPH levels in sediment range to 35,000 ppm. PAHs were also detected, probably contributed by municipal storm drains. Surface water has been determined to contain bis(2-ethylhexyl)phthalate at 1,100 parts per billion (ppb). Subsurface soil contains ethylbenzene, toluene, chlorobenzene, TCE, as well as rubber fill materials. Groundwater analyses detected xylenes, toluene, ethylbenzene, benzene, chloroethane, chlorobenzene, 2,4-dimethylphenol, N-nitrosodiphenylamine, phenol, naphthalene, and bis(2-ethylhexyl)phthalate. In addition, an oil spill was reported into Sawins Pond in 1976.
- MADEP Site No. 3-3210. A property owned by UPS at which two diesel USTs were removed, one of which had ruptured and caused substantial contamination of the surrounding soil.
- MADEP Site No. 3-2538. The Watertown Mall site, under which a stream drainage system originating on the Boston Edison property passes. This site was formerly a part of the Hood Rubber property. A settling basin in the system was analyzed, and mercury, cadmium, lead, TPH, PCBs, and SVOCs were found.

In addition to the MADEP listed sites, there are 5 Sites listed on the USEPA Comprehensive Environmental Response, Compensation and Liability Act Information Systems (CERCLIS) Database which are part of the Superfund program (ABB-ES, 1993). Several of those sites are listed below:

- MAD981212871. DKM Management. This property borders Sawins Pond. Refuse materials have apparently been dumped along the edge of the pond on this site, and unauthorized waste liquids may have been discharged from a pipe located on the DKM property into the ponds. Barclay Chemical and University-Brink, Inc. are occupants of the DKM property and have been mentioned in incidents concerning activities at Sawins Pond.

- MAD981212897. Fillippello Playground. The Playground was established at the site of the former Watertown Dump. The landfill extended from Arlington Street to Grove Street and was active until approximately 1973. The landfill accepted municipal wastes, wastes from the Hood Rubber Company, rubbish from the Watertown Arsenal, and metal wastes from AMMRC machining operations. These metal wastes reportedly contained “magnesium, bronze, and perhaps other metals.” Because detailed radioactive waste disposal records are not available, MADEP identified the former dump as a potential recipient of radioactive wastes. The NRC declined to investigate the former dump based on the lack of evidence indicating that radioactive wastes were sent to the dump. The landfill was covered with clean fill and graded prior to landscaping for use as a park and playground.

- MAD981212889. Hood Rubber Property. Rubber manufacture was ceased at this property in 1969, and the original property was subsequently occupied by the Watertown Mall, Boston

Edison, and United Electric Controls. Sawins and Williams Ponds were part of the original Hood property. Waste rubber products were discarded along the northern banks of Sawins Pond, and latex rubber oils and solvents may also have been discarded in the Sawins Pond area.

- MAD981069842. Sawins and Williams Ponds. Potential sources of contamination at Sawins and Williams Ponds are mentioned under the headings for other sites in this summary.

- MAD213820939. U.S. Army Materials and Technology Lab (AMTL). Potential sources of contamination at the AMTL include lubricating oil, metal cuttings, foundry wastes, solvents such as TCE, and raw materials such as magnesium, manganese, chromium and carbon.

5.0 PREVIOUS INVESTIGATIONS

5.1 ARSENAL DECONTAMINATION ACTIVITIES OF 1966 AND RADIOLOGICAL SURVEY OF 1967

Arsenal personnel performed decontamination activities at the Site in late 1966. These activities included radiological surveys and soil removal, but many specifics relating to the survey and decontamination are not available. The northeast portion of the Site was gridded into 6-by-6 foot squares and surveyed for radioactivity (NRC, 1993). The grid extended from the fenced burn pit area approximately 75 feet southwest towards the on-site buildings and extended from the fence along the northwest side of the property to the fence along the southeast side of the property. Contaminated soil was collected using bulldozers and payloaders and generally included the top 6 to 12 inches of soil, which was then stored in dumpsters and subsequently shipped offsite for burial at the Maxey Flats Kentucky low-level radioactive waste disposal facility. The radiological surveys were repeated after soil removal, and remaining isolated areas of residual contamination were excavated. Excavation work was reportedly halted due to frost conditions (NRC, 1993), and the area with detectable residual radioactivity was enclosed with a chain link fence. A final radiological survey was performed over the area, and the results were submitted to the Army (ABB-ES, 1993).

The results of the 1967 radiological survey performed following the excavations reported only three fixed alpha readings greater than zero disintegrations per minute (dpm) in 81 readings collected outside of the fenced burn area. The highest of these readings was 100 dpm, measured about 20 feet southwest of the burn area fence. Measurements within the enclosed burn area surrounding the concrete pad indicated fixed alpha readings up to 155,000 dpm and fixed beta-gamma readings up to 1.5 micro-Roentgens per hour (μR/hr). Measurements of the concrete pad itself indicated fixed alpha readings up to 1,700 dpm and fixed beta-gamma readings up to 45 μR/hr. Removable radioactivity was also measured on the concrete pad with alpha measurements ranging from 0 to 24 micro-nucro curries per 100 square centimeters (μμCi/100cm²) and beta measurements ranging from 0 to 90 μμCi/100cm² (ABB-ES, 1993).

The survey results indicated that the area was contaminated with respect to the license conditions for radioactivity contamination limits, and the AEC denied the Army's request to release the area to the GSA while in its contaminated state. The release was later approved on the condition that the AMMRC retain control of the contaminated areas under their AEC license, SUB-238 (ABB-ES, 1993).

5.2 1973 RADIOLOGICAL SURVEY

AMMRC personnel performed a further radiological survey, the results of which are documented in a report from October of 1973. AMMRC sought to release the Site to GSA for unrestricted use, but was required to meet criteria outlined in the AEC "Guidelines for Decontamination of Termination of Licenses for Byproduct, Source, or Special Nuclear Material" dated April 1970. The survey results from 1967 indicated fixed surface levels significantly above these AEC criteria, and detected uranium concentrations in soil samples. Because the AEC lacked specific cleanup criteria for soil, Sidney Levin, the Safety Director at the AMMRC, personally researched

the issue and established the soil standards that he would seek to comply with during decontamination of the Site. The AEC accepted the survey results obtained after the decontamination activities as being in accordance with the limits that Mr. Levin had determined pursuant to the existing AEC guidelines (ABB-ES, 1993).

The survey was undertaken only within the burn area, and found residual surface radiation on the concrete pad and soil surface, but no removable radiation. Penetrating radiation measurements included both on-contact measurements and measurements at 3 feet above the ground surface. Instrumentation consisted of an Eberline Geiger Counter, model E-500-B and an Eberline Portable Alpha Counter, Scintillation Type, Model PAC-1SA, with an effective probe area of 59 cm^2. The concrete pad in the burn area was surveyed for fixed alpha and beta-gamma radiation levels. The burn pit area was surveyed for beta-gamma soil radiation levels, and soil samples were collected. The highest soil concentration level was 9.5 µg/g of uranium, which was accepted by the AEC as a background level (NRC, 1993). The surveyed ground area measured 70 by 100 feet and included a 20 by 30 foot concrete pad.

As with the 1966 and 1967 projects, more specific detail on the surveying process is not available. An unknown quantity of soils and fill materials identified as contaminated were removed from the burn area and disposed of at either Maxey Flats, Kentucky or West Valley, New York as part of the decontamination process.

5.3 ANL RADIOLOGICAL SURVEY OF THE FORMER WATERTOWN ARSENAL PROPERTY GSA SITE, CONDUCTED FOR THE DOE IN 1981

ANL undertook a radiological survey of the Site in 1981 as requested by the DOE because prior documentation for the GSA Site was insufficient to determine whether the decontamination work done to release the Site for unrestricted use met then current ANSI 13.12 and NRC guidelines.

The survey consisted of several parts. Instrument surveys were performed to measure radiation levels on all accessible building surface areas, interior and exterior, of Buildings 234 to 237. In addition, smear surveys of building surface areas were taken where deemed appropriate, soil samples were collected at representative locations, and subsurface soil sampling and bore hole logging were performed at select locations. For the purpose of the survey, the site was divided into six zones. Zone I was defined as the burn area. Zone II was the clinker area, Zone III consisted of the paved areas surrounding the buildings, and Zone IV was the area beyond the security fence to the west. Zone V consisted of the area beyond the northern security fence, and Zone VI was the area outside the fence to the east. Zone locations are shown in Figure 5-1. Air sampling was conducted at several locations, and sewer, water, and sludge (sediment) sampling was done where possible. A pressurized ion chamber was also used to determine ambient radiation levels at the 3 foot level. The land area was gridded into 100 foot square reference areas for the purpose of the survey. Figure 5-2 shows areas found to have elevated measurements by the area instrument surveys. Appendix C contains radiological data collected by ANL.

5.3.1 Methodology

5.3.2 Instrumentation

Four types of survey instruments were used to conduct the direct radiological surveys. Gas-flow proportional detectors with window areas of 51 cm² and 325 cm² (using Eberline PAC-4G-3 electronics) were used to monitor for alpha and/or beta-gamma radiation. Background and alpha contribution were subtracted from gross readings taken in the beta mode to determine the net beta-gamma count rate, which was then converted to disintegrations per minute (dpm) and normalized to a surface area of 100 cm². Since instrument calibrations were to infinitely-thin, flat-plate standards, all reported readings should be regarded as minimal values; no corrections were made for absorption by surface media.

NaI crystal detectors, 5 cm diameter by 2 mm thick (Eberline PG-2 with Eberline PRM-5-3 electronics), were used to monitor for low-energy x-ray and gamma radiation. The results are reported in counts per minute (cts/min) and include 500 cts/min of instrument background. NaI crystal detectors, measuring 2.5 cm in diameter by 2.5 cm thick (Eberline PRM-7 μR meter) and calibrated with a Ra-226 standard source were used to measure the ambient external penetrating radiation field in units of μR/h. The measurements include instrument background of 7 to 10 μR/h.

An end-window Geiger-Mueller detector (Eberline HP-190 with a 7 mg/cm² window and Eberline 530 electronics), calibrated with a Ra-226 standard source, was used to measure the contact exposure rate, in μR/h, of contaminated areas. These measurements include the instrument background of 0.03 μR/hr. Time integrated measurements of the ambient penetrating radiation field were taken with a residual activity Reuter-Stokes RSS-111 pressurized ionization chamber calibrated with a National Bureau of standards (NBS) traceable gamma-ray source.

When possible, residual activity was identified by performing gamma spectral analysis on the potentially contaminated item, on a sample of material taken from the potentially contaminated item, or on a sample of material taken from a potentially contaminated area. These analyses were performed with a sodium iodide or HyperPure Germanium detector coupled to a multi-channel analyzer.

Smear Surveys

Within the buildings, dry smears were taken at representative locations with 4.25 cm diameter filter papers (Whatman #1). Standard smear samples were obtained by applying moderate pressure with the tips of two fingers to the back of the filter paper and wiping the surface over an area of approximately 100 cm². Smears were taken on original structures and components such as walls, floors, pipes, and vents. A smear of 100 cm² was taken from any area or object indicated by a portable survey instrument to have a higher than normal radiation level. Smears of 100 cm² were also taken if the surface was extremely dusty. Two counting techniques were employed with two types of counters. A large-area, thin-window, gas-flow proportional counter, sensitive to alpha and/or beta-gamma radiation was used to make an initial count on groups of smears. For confirmatory counts on individual smears noted to be above the expected background level, a Nuclear Measurement Corporation Model PC-5 or 3A internal gas-flow proportional counter (PC counter) with a thin aluminized Mylar window was used.

Initial counts were made with the large-area counter on groups of ten smears at a time. Smears from any group indicating a reading above the instrument background were then counted individually in the PC counter. All smears of the areas of objects with elevated direct readings were counted individually in the PC counter. Smear samples were counted for both alpha and beta-gamma activity, and the net count rates are converted to dpm per 100 cm^2 after subtracting the appropriate background.

Air Samples

Air-particulate samples were collected using a commercial vacuum cleaner modified by ANL to pull air through filter media (Hollingsworth-Vose HV-70). A total volume of 26.7 m^3 of air was sampled at a flow rate of 40 m^3/h. A 10 percent portion (5 cm in diameter) was removed from the filter media after collection and counted for both alpha and beta-gamma activity in the PC counter. Concentrations of Rn-222, Rn-220, and the presence of any long-lived airborne radionuclides were determined based on the result of several counts of each sample at specified intervals. Air-particulate samples were also collected on Millipore membrane filter media for 40 minutes at a flow rate of approximately 1 m^3/h. A portion of each filter sample was used for alpha spectral analysis to determine the Rn-219 concentration.

Soil Corings

Soil samples 4 inches in diameter and 12 inches deep were collected from selected undisturbed locations throughout the site (Figure 5-3). Six soil corings were collected from Zone I, nine from Zone II, three from Zone III, three from Zone IV, six from Zone V, and one from Zone VI. Four additional corings, two 4.2 miles away in Newton, and two 8.6 miles away in Stoneham, were also collected to determine background levels of radionuclides in the soils of the area. Uranium fluorometric and gamma spectral analyses were conducted on all samples.

Each soil core was evaluated in four segments. The first three segments proceeding down from the surface were two-inches long, and the final segment was six-inches long. The segmented coring technique was used to determine whether any contaminant migration had occurred, to reduce the dilution of lower-level soil with the upper-level segments with respect to the surface deposition of the contaminants (or vice-versa), and to reveal whether any overburden or backfill had been added.

Soil Borings

Bore holes were drilled in areas exhibiting elevated radiation levels. Samples were collected from the hole in sequential 1 foot sections using a split-spoon sampler with a 1½ inch inside diameter (ID). The depth of the bore holes ranged to six feet. Each boring was identified with a number, and each sample was identified according to the depth in feet of the bottom of the sample. Depths were reported to the nearest tenth of a foot. Soil boring locations are shown in Figure 5-4. Six borings were drilled in Zone I, four in Zone II, and nine in Zone V.

Soil Analyses
Soil samples were analyzed either by ANL or by a contract laboratory. All samples were analyzed using GeLi gamma spectroscopy and radiochemical analyses for uranium using laser fluorometry.

5.3.3 Building Instrument and Smear Survey Results

Instrument and smear surveys were performed in buildings 234, 235, 236, and 237. The survey results were reviewed with respect to both the ANSI Standard N13.12, "Control of Radioactive Surface Contamination of Facilities to be Released for Uncontrolled Use," and the NRC's "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material." No interior residual radioactivity was detected in any building on the Site, with approximately 75% of the walls and floors surveyed. Overheads were also subjected to instrument and smear surveys, and the floors and walls had smear samples taken at selected locations. Each building was scanned at an elevation of about 1 m above the surface with a μR gamma survey instrument. Integrated measurements of the ambient penetrating radiation field were also taken inside each building with a pressurized ionization chamber. All levels were within the established background.

5.3.4 Outdoor Instrument and Smear Survey Results

Burn Area (Zone I)
Instrument surveys were conducted over the entire area using the four types of portable survey instruments described above. Elevated concentrations of radioactivity were found at 13 locations within the burn area, shown as locations 34 through 46 on Figure 5-2. Alpha activity was detected at locations 39, 40, and 45. DU chips were found at locations 39 and 40, and it was determined by subsequent mass spectrometric analyses of several samples that the results were due to DU. Ambient radiation levels were measured with a pressurized ionization chamber at two locations in this zone. The levels measured with the RSS-111 instrument at locations 1 and 2 were 17.7 and 11.6 μR/h, respectively, and the corresponding PRM-7 measurements were 34 and 13 μR/h.

Clinker Area (Zone II)
This area contained 25 locations with elevated radioactivity concentrations, numbered 47 through 71. The elevated concentrations were found primarily in the northern portion of the section. Most locations were relatively small, although one area (locations 59, 61, 62, and 63) covered about 5 m^2. Three ambient radiation measurements were taken with the pressurized ionization chamber, at locations 3, 4, and 7. The RSS-111 measurements were 9.8, 11.7, and 7.5 μR/h, respectively, and corresponding PRM-7 measurements were 7, 10, and 5 μR/h.

Paved Area (Zone III)
No elevated readings were found in this area, although a wire with a contact reading of 3 μR/hr was found. Preliminary gamma spectral analysis indicated that the reading was due to Ra-226 in equilibrium with its daughters. No locations with levels above background were found based on the instrument survey, and ambient radiation levels were measured with the pressurized

ionization chamber at locations 5, 6, and 10. RSS-111 measurements were 10.7, 12.6, and 10.0 μR/h respectively, and the corresponding PRM-7 measurements were 9, 11, and 10 μR/h.

Western Boundary Area (Zone IV)
No elevated radioactivity was found in this zone, although the radiological survey of the area revealed noticeable variability in the instrument readings depending on the type of surface. The ambient radiation level in this zone was measured in one location, with a RSS-111 reading of 10.2 μR/h, and a corresponding PRM-7 reading of 10 μR/h.

Zone V (North of the Burn Area)
A few localized areas, totaling less than 1800 cm^2, exhibited somewhat elevated radiation levels. These locations are labeled as locations 72 through 89 on Figure 5-2. The report suggests that the elevated levels may be the result of natural radioactivity in the fill material. In light of the findings in later reports, however, it seems possible that the elevated readings may be a result of the presence of tailings material from the MIT/Cyanamid research. Ambient radiation levels at locations 8, 21, and 22 were 9.6, 14.6, and 12.4 μR/h respectively as measured by the RSS-111, with corresponding PRM-7 readings of 10, 15, and 12 μR/h.

Eastern Boundary Area (Zone VI)
A marshy area in the northern third of this zone prevented a complete surface survey; no elevated radioactivity was detected by the instrument survey of this section.

5.3.5 Soil Corings

Throughout the Site, 23 soil corings were conducted in areas which had been identified as potentially contaminated by the surface surveying. The corings were 4 inches in diameter and extended 12 inches deep. In addition, a rock sample (1-R96) was taken from an outcrop in Zone IV, and four soil scrapings were collected (1-S76, 1-S102, 1-S105, and 1-S106). Soil coring, rock sample, and soil scraping locations are shown in Figure 5-3.

All soil corings were sectioned and analyzed for uranium (uranium fluorometric) as well as radium and thorium decay chains (gamma spectral analysis). A total of four background soil corings were taken at two offsite locations to determine background levels of radionuclides in soil. These corings, identified as 1-SB107 through 1-SB110, were analyzed as above. These background samples indicated natural uranium concentrations ranging from 0.9 to 4.6 pico Curies per gram (pCi/g), with one exception. Sample 1-SB110B (from 2-4" bgs) had 11.8 pCi/g of natural uranium, probably as a result of soil fertilization (ANL, 1983).

These samples revealed several areas with significantly high levels of radioactivity. Results of lab analysis of the soil corings showed concentrations to be as high as 2.6×10^4 pCi/g (1-S104), with three samples having readings higher than 10^4 pCi/g (1-S104, 1-S105, 1-S106). Of the nine remaining samples with elevated activity, 5 had readings in excess of 100 pCi/g (1-S47, 1-S48, 1-S49, 1-S50, 1-S99). None of the samples showed elevated levels of radium or thorium as determined by gamma spectral analysis of the radium and thorium decay chains. Based on these findings, the radioactivity was determined to consist of other than natural uranium.

5.3.6 Soil Borings

Soil borings were advanced in areas of elevated radioactivity, as established by the soil corings, in an effort to establish a vertical profile. A total of 19 borings, labeled 1-S77 through 1-S95, were drilled to a depth of 6 feet, the maximum permitted by the groundwater level at the Site. Soil boring locations are shown on Figure 5-4.

Bore-hole logging was accomplished using a 2 inch by 2 inch NaI (Tl) detector in conjunction with a ND-100 multichannel analyzer. Readings were taken at grade level and at two foot increments thereafter. The results of the logging did not reveal any unexpected anomalies.

Split spoon samples were collected at continuous 1 foot increments. Each soil sample was analyzed for uranium (uranium fluorometric) as well as radium and thorium decay chains (gamma spectrometric). The absence of the Ra-226 decay chain in most of the samples revealed that the bulk of the radioactivity detected was due to uranium which had been chemically separated from its daughters. Mass spectrometric analyses were performed on several of the soil samples with the highest measurements. These analyses were made to determine whether the elevated uranium concentrations resulted from DU, as had been reported. All of the samples except 1-R96 were depleted in the U-235 isotope, confirming that the elevated radiation levels were due to DU. Sample 1-R96 was not a soil sample, but a sample taken from a rock outcropping in zone IV. Elevated radiation levels in this sample were determined to be due to natural thorium and uranium indigenous to the site. The sample had the equilibrium concentration of Ra-226, as would be expected for natural uranium.

Two borings (1-S92 and 1-S95) contained elevated Ra-226, indicating the presence of uranium tailings material. 1-S92 had a radium concentration of 14 pCi/g. Although 1-S95, located along the northern perimeter of the GSA Property, had a reading of only 5 pCi/g, this concentration was continuous to the bottom of the boring at 6 feet. At the 6 foot depth, the measurement for Ra-226 was 4.18 pCi/g, and the Uranium Fluorometric measurement was 9.2 pCi/g.

Three borings (1-S87, 1-S91, and 1-S94) showed equilibrium concentrations of the Ra-226 decay chain, indicating the presence of natural uranium. These concentrations were relatively small (up to 12 pCi/g of uranium) and were restricted to the first few feet of soil.

Thirteen borings had elevated measurements due to other than natural uranium. The maximum concentration was 588 pCi/g, in 1-S85. The borings with the highest concentrations (1-S81 through 1-S86) were all located in Zone I. The elevated measurements were found as deep as 6 feet in five borings (1-S80, 1-S81, 1-S83, 1-S84, and 1-S85). All of these borings were located in or near the burn area, and with the exception of 1-S80, which is located just to the northeast of the burn area, have likely been altered by later remediation activities in the burn pit. The detected radiation at the 6 foot depth ranged from 3.2 pCi/g at 1-S84 through 3.5 pCi/g at 1-S80 to 14.5 pCi/g at 1-S83.

5.3.7 Water and Sediment Sampling

Surface water and sediment samples were collected from Sawins Pond Brook both upstream and downstream from the Site, and from a swampy area north of the property. Surface Water and

sediment sampling locations are shown on Figure 5-5. In addition, groundwater samples were collected from bore holes 86, 90, 91, 92, 93, and 95. Water samples were separated into suspended solids and dissolved solids fractions, and each fraction was analyzed for uranium (uranium fluorometric) and the Ra-226 and Th-232 decay chains (gamma spectrometric). No anomalous levels of radioactivity were found in the dissolved solids fractions, but three samples (1-W69, 1-W86, and 1-W91) had elevated uranium levels in the suspended solid fractions. This uranium was judged to be other than natural, probably depleted, since the Ra-226 decay chain levels were normal in all the samples. One of the samples with elevated uranium came from outside the fence, at the corner of the fence near Building 235 (1-W69). The other samples judged to have elevated concentrations of DU were in the burn area (in boring 86, with 55pCi/g of uranium), and about 50 feet northeast of the burn area (in boring 91). The report concludes that uranium was being transported by suspended particles in the groundwater (ANL, 1983). *However, these samples were not taken from properly installed monitoring wells, and the presence of uranium in the suspended solids fraction is to be expected given the presence of uranium in the surrounding soil. These suspended solids are likely the result of the sampling method rather than particles actually moving through the groundwater at the site. This hypothesis is supported by the findings of later surveys, which did not find elevated concentrations of uranium in the groundwater.*

5.3.8 ANL Conclusions

The ANL survey concluded that approximately 65 ft² of ground surface area, consisting of both soil and concrete, exhibited elevated radiation levels, and soil borings indicated that the elevated concentrations of radioactivity extended to at least 6 feet in depth at some locations. Contaminated material was thus in contact with groundwater, raising the risk of contaminant transport via suspended particles in the groundwater (ANL, 1983).

5.4 CNSI COMPREHENSIVE SITE ASSESSMENT SURVEY AND REMEDIATION, 1990

CNSI conducted a study covering both chemical and radiological constituents following the halt of their remediation work in the burn area. CNSI was originally retained to remove soil and building rubble contaminated with DU, which had been characterized both by the ANL report, and by a CNSI survey in 1988. During the burn area excavation, an oily sludge was uncovered, and work was stopped in order to respond to this oil and hazardous material (OHM). A field program to produce a Comprehensive Site Assessment was then instituted in 1990. The radiological data collected as part of this investigation are included in Appendix D.

The CNSI field investigation was conducted in accordance with the MCP requirements in effect at the time. The investigation consisted of:

- the installation of 31 shallow (10 to 17 foot) and 4 deep (48-51 foot) borings
- installation of 11 shallow and 4 deep monitoring wells in selected borings to evaluate the aquifer and analyze the ground water quality in the two uppermost hydrologic units
- groundwater sampling
- marsh and sediment sampling
- surface water sampling
- a topographic elevation survey

- aquifer hydraulic conductivity tests.

5.4.1 Soil Boring Installations

Shallow soil borings were continued through an upper fill layer into an underlying peat and terminated at depths of 10 to 17 feet. Four deep borings were driven to depths of 48 to 51 feet, into the stratified sand layer beneath the peat, and completed as monitoring wells. Twenty shallow borings, B-1 through B-20, were completed solely to collect samples for radiological and or chemical analysis and geologic characterization of the shallow overburden. Eleven shallow borings were to facilitate the installation of shallow monitoring wells (Wells indicated by a "W" are stand-alone shallow wells, while wells indicated by "WC" are part of a deep-shallow well cluster.). Figure 5-6 shows the locations of the wells and soil borings. The borings were placed in the following groups:

- Seven shallow borings were positioned on the anticipated upgradient or westerly side of the property to assess potential contaminant impacts to soil and groundwater from upgradient sources. (WC-1, W-7A, W-9A, B-2, B-3, B-4, B-5).
- Eight borings were positioned on the suspected downgradient or easterly portion of the site to assess conditions on the downgradient site boundary (WC-4, WC-5, WC-8, W-10A, B-1, B-16, B-17, B-19).
- Four borings were placed surrounding the burn pit (B-8, B-9, B-10, B-11).
- Eleven borings were placed at selected areas throughout the rest of the site to provide additional data at other potential source areas (WC-2, WC-3, W-6A, B-6, B-7, B-12, B-13, B-14, B-15, B-18, B-20).
- One shallow well was located downgradient of an abandoned underground fuel oil storage tank near Building 235 (W-11A).

Soil borings were excavated with 4-¼" ID hollow stem augers, and soil samples were collected by split spoon at five foot intervals in the shallow borings. Borings B-8 through B-11 were sampled continuously to a depth of 10 feet, which generally represented the bottom of the fill layer. Each sample was classified according to the Unified Soil Classification system and field screened with an HNU Model PI-101 photoionization detector calibrated to a benzene equivalent.

Samples were selected for analysis from the borings based on visual observations and field screening results. Analysis included VOCs, SVOCs, 13 total metals, total petroleum hydrocarbons (TPH), 8 toxicity characteristic leaching procedure (TCLP) extractable metals, and total uranium. In the deep borings, samples were collected every five to ten feet from a depth of 20 to 50 feet, and each sample was analyzed for total uranium.

5.4.2 Monitoring Well Installation

In shallow monitoring wells, screens were set 6 to 9 feet below the groundwater table. In areas where the groundwater table was at or near the surface, 10 feet of screen was set to 11 feet bgs. Efforts were made to bracket the water table with the well screens such that floating non-aqueous phase petroleum hydrocarbon liquids could enter the well. In borings where the water table was at or close to ground surface, the top of the well screen was set 1 to 2 feet below the surface to prevent surface water from entering the well and to provide adequate length for sealing. In deep

monitoring wells, screens were set at a depth of about 40 to 50 feet, and a bentonite seal was installed to prevent the introduction of water from the upper aquifer.

5.4.3 Soil Sampling Results

5.4.3.1 TPH

Soil samples to be analyzed for TPH were usually collected at three depths: 0 to 2 feet, 5 to 7 feet, and 10 to 12 feet bgs at each boring location. Elevated TPH levels are present in all three sampled intervals, with fewer non-detectable concentrations in the lower interval. For the most part, detectable concentrations were elevated and typically ranged from 1 to 3,000 ppm. Contamination was judged to originate at the burn pit and the UST as well as an unidentified source in the middle of the clinker area. This area in the center of the clinker area appears to be approximately the same as the location of the tower, which the PAL report describes as having been present in the 1950s. The tower location is shown in Figure 4-1. Contamination also appeared to be related to a buried concrete structure which CNSI discovered in the northern portion of the Site. TPH compounds may have been introduced through groundwater transport, but due to the extensiveness of contamination, the fill placed on-site may also have originally contained some degree of contamination.

5.4.3.2 VOCs and SVOCs

The intervals analyzed for VOCs and SVOCs were selected based on observations, results of field screening, and location with regards to suspected sources of contamination, such as the burn area. Relatively low VOC and SVOC concentrations were detected, and seemed generally to be related to the burn area or to TPH contamination. Volatile compounds were not detectable except for low concentrations of acetone in borings WC-1A, W-10A, and B-19, and 2-butanone in W-10A. Acetone was also detected in the sludge sample collected from the burn pit at the close of remediation activities. The maximum detected concentration of acetone was 440 µg/kg in W-10A, and the maximum 2-butanone concentration was 140 µg/kg, also in W-10A. Several PAHs were detected in various concentrations and combinations in the soil samples. PAHs detected included fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(k)fluoranthene, benzo(A)pyrene, indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, acenaphthene, phenol, and 4-methylphenol. The residues found were consistent with incomplete combustion of wood, heavier weight fuel, tar, or rubber.

5.4.3.3 Metals

Generally, a surface sample and one other sample from a greater depth (either 5 to 7 or 10 to 12 feet bgs.) were analyzed for the eight RCRA metals by TCLP. Total metals analyses were performed on six representative surface soil samples scattered throughout the site (B-3, B-6, B-9, B-19, B-20, and W-9A). No background soil analysis data for the area could be located in the CNSI report. A comparison was made between levels found at the site and the typical ranges of native metal concentrations in soils in Dragen's 1988 "The Soil Chemistry of Hazardous Materials." Typical native concentrations for lead (200 ppm), mercury (0.08 ppm), silver (5 ppm), and zinc (300 ppm) were exceeded in many borings. Lead concentrations in borings B-3, B-19, and B-9 were 860 ppm, 380 ppm, and 2,100 ppm, respectively. Mercury concentrations were

0.1210 ppm in B-3, 0.2626 ppm in B-6, 0.3833 ppm in B-9, 0.2023 ppm in B-19, and 0.1438 ppm in MW-9A. The silver concentration at W-9A was 5.3 ppm, and the zinc concentrations at B-3 and W-9A were 494 ppm and 1,000 ppm, respectively.

In three borings, metals concentrations exceeded EPA TCLP limits established in 40 CFR Part 261 II (G) – twice for cadmium (in the 0 to 2 foot interval of W-5A [1.08 mg/L] and in the 0 to 2 foot interval of B-12 [2.38 mg/L]) and once for lead (in the 0 to 2 foot interval of B-10, at 6 mg/L).

5.4.3.4 Total Uranium

Samples were collected for total uranium analysis from each sample interval of all borings in which there was sufficient sample recovery. CNSI states that previous analytical results strongly suggest that the uranium present on-site is primarily DU. All total uranium results were below the DU clean up level of 35 pCi/g except for one sample, the 0 to 2 foot interval in boring B-13, which measured 330 pCi/g. In addition, previous samples collected in the burn area indicated much higher levels of uranium to be present at a depth of 8 to 10 feet. Samples collected by this field investigation in borings B-8, B-9, B-10, and B-11 did not indicate elevated uranium levels.

Radiological surveys performed by CNSI also indicated elevated levels in the area around boring B-13, with the boring location itself corresponding to the area with the highest measured penetrating radiation level (15μR/hr as measured with an Eberline ESP-1 with a SPA-3 [NaI] probe in a ratemeter mode). The 0 to 2 foot split spoon sample measured 11.2 μR/h and 30,875 dpm per probe, equivalent U-238 (as measured with an Eberline ESP-1 with a HP-210(T) (7G-M tube) probe in a ratemeter mode). A survey performed in the burn area prior to work indicated some isolated elevated radiation levels (up to 30 μR/h) to be present.

CNSI concluded that the only areas of the site which exceeded DU clean-up levels of 35 pCi/g in soil were the burn pit area, bounded by borings B-8 through B-11, and the isolated area around B-13. CNSI did not gather enough data to determine the depth of elevated DU concentrations in the burn pit, but their data for boring B-13 indicated that the elevated concentrations were restricted to the upper 5 feet of the soil.

5.4.4 Groundwater Sampling

Two rounds of groundwater sampling were performed in the newly installed wells. An initial round was conducted on July 25 through 27, 1990, and a confirmatory round was conducted on August 6, 1990. Each well was purged of three casing volumes of water prior to sampling. On the first round, analysis was for VOCs, SVOCs, eight RCRA metals by TCLP, TPH, and total uranium. Second round analyses did not include total uranium.

5.4.4.1 TPH

Detectable TPH concentrations were found in groundwater collected from wells screened both in the shallow fill layer and in the deeper sand layer. Contamination was found in shallow wells 5A, 6A, 7A, 9A, and 10A in the central and southwestern portions of the Site during the first round and in shallow wells 2A, 5A, and 11A downgradient from the burn pit and near the abandoned

UST during the second round. Concentrations ranged from 6.7 ppm (in W-7A) to 82 ppm (in W-6A) during the first round of sampling, and from 7.6 ppm (in WC-5A) to 19 ppm (in W-11A) during the second round.

In the deep wells, the first round of sampling detected concentrations of TPH in two wells, 7.3 ppm in WC-5C, and 10 ppm in WC-10B. The second round of sampling did not detect any TPH.

TPH detection in groundwater samples corresponds to TPH detection in soil samples. In addition, the concentrations of petroleum hydrocarbons solublized in groundwater relative to the concentrations in soil samples suggest that a large portion of the petroleum hydrocarbons present in the subsurface of the site are bound to the soil matrix.

5.4.4.2 VOCs and SVOCs

VOC and SVOC analyses of groundwater samples produced frequent detection of methyl-t-butyl ether (MTBE), which has been used as a gasoline additive since 1980, in many of the shallow and deep wells across the Site. MTBE concentrations were similar in both sampling rounds, and greatest in the deep sand wells. Concentrations ranged from 175 ppb (parts per billion) in upgradient well WC-1B in the western portion of the site down to 12 to 64 ppb in downgradient wells (WC-4B, WC-5C, and WC-10B). MTBE was detected at lower concentrations in the shallow wells, ranging from trace to 17 ppb. CNSI concluded that the presence of MTBE represented the leading edge of a gasoline plume in the lower aquifer, with contamination having slowly migrated up through the peat layer due to the difference in hydraulic head between the two aquifers.

Additionally, relatively low concentrations of halogenated compounds were detected in one deep (WC-4B) and three shallow (W-7A, W-9A, and W-11A) wells. Well W-9A contained 20 µg/L of 1,1-dichloroethene (1,1-DCE), 13 µg/L of trans-1,2-dichloroethene (trans-1,2-DCE), and 7 µg/L of TCE. Well W-7A contained trace trans-1,2-DCE, well W-11A had trace trans-1,2-DCE and methylene chloride (MC), and well WC-4B contained trace 1,2 1,2-DCE, trace 1,1-DCE, 6 µg/L of TCE, and 10 µg/L of trans-1,2-DCE. Since concentrations of 1,1-DCE, trans-1,2-DCE, 1,2-DCE, and TCE were found downgradient in WC-4B, but not upgradient of the burn area (in WC-1B) in deep wells, these concentrations may originate in releases from the burn area - concentrations of TCE and trans-1,2-DCE were found in the sludge sample from the burn pit.

Other VOC and SVOC contaminants detected included carbon disulfide at 22 µg/L in well W-9A during the first round of sampling, naphthalene at 24 µg/L in W-8A, and trace concentrations of the semi-volatile compounds bis(2-ethylhexyl)phthalate in W-7A during the first round of sampling, phenanthrene in wells WC-4A and W-11A during the first round and W-11A during the second round, and 4 methylphenol in WC-10A during the second round of sampling.

5.4.4.3 Metals

Barium and mercury were detected below regulatory limit values during the first round of testing. Barium was found in wells 1A, 2A, 3A, 4A, 5A, 7A, 8A, 1B, and 4B, at concentrations ranging from 0.03 ppm to 1 ppm. Mercury was found in wells 1A, 3A, 4A, 1B, and 4B at concentrations

of 0.0002 and 0.0003 ppm. Barium and mercury were detected during the second round as well, barium in wells 2A, 3A, 4A, 5A, 6A, 7A, 8A, 10A, 11A, 5C, and 10B at concentrations from 0.07 ppm to 0.80 ppm, and mercury in well W-3A at 0.0002 ppm. All detections were below the regulatory limit values.

5.4.4.4 Total Uranium

Three wells exhibited detectable total uranium concentrations of 0.27 pCi/L (shallow wells 7A, 8A, and 9A), and one well produced a result of 0.34 pCi/L (deep well 1B). These concentrations are consistent with the naturally occurring concentrations expected in unaffected groundwater and are significantly below the proposed federal drinking water concentration limit for drinking water (20 µg/L or 13.7 pCi/L). In addition, these concentrations are well below the State of Massachusetts guideline levels for drinking water (20 µg/L). All other wells were below detection limits. Of the wells which exhibited the presence of uranium, only one soil sample from the corresponding boring exhibited a detectable concentration: 2.7 pCi/g at the 12 to 14 foot interval of W-8A. Five other borings (wells 1A, 2A, 3A, 10A, and 10B) which exhibited detectable uranium in two or more intervals of soil had no detection of uranium in the corresponding groundwater sample. The sampling protocol followed by CNSI involved filtering the samples to remove particulate matter, which might have removed the uranium which ANL found to be present in the suspended fraction. In addition, the groundwater detection of uranium occurred in areas removed from the burn area, suggesting that the burn pit is not contributing uranium to the groundwater. *Because CNSI's water samples were collected from properly installed monitoring wells rather than open boreholes, the data is likely more reliable than that collected by ANL. Further discussion of groundwater results is included in section 6.1 below.*

5.4.5 Sediment and Surface Water Sampling

Sediment and surface water samples were collected at four marsh locations along Greenough Boulevard and at two locations in Sawins Pond Brook, one set of samples 20 feet downgradient of the existing bridge and a second at the mouth of the culvert in the southwest portion of the Site, two days after a rainfall event. For marsh sampling, a composite of the top 6 inches of soil was collected, and the water from the depressions excavated was then collected and analyzed. Marsh and stream samples were analyzed for TPH, Total Uranium, and RCRA 8 TCLP Metals, and stream surface water samples were also analyzed for VOCs and SVOCs. Figure 5-7 shows the locations of sediment and surface water sampling.

5.4.5.1 Sediment Sampling Results

TPH

TPH analyses showed elevated concentrations ranging from 5,040 ppm to 15,400 ppm in each of the four marsh sediment samples. Although the samples were intentionally collected in areas which contained discoloration and exhibited oily sheens, the elevated concentrations could potentially occur in a large portion of the marsh sediments. The stream sediments also exhibited elevated TPH concentrations at both the up- and downgradient points, with results of 8,380 ppm and 14,300 ppm respectively.

CNSI suggests that hydrocarbon residues in the stream are probably primarily related to similarly high levels present upgradient in Sawins Pond. CNSI also suggests that some petroleum hydrocarbon residues present in the marsh sediments may have originated in the pond, having been transported to the marsh during flood events.

Metals
TCLP concentrations for metals were all either non-detectable or well below regulatory levels established in 40 CFR 261, Final Rule. Barium was present at 0.08 to 0.18 mg/L, cadmium at 0.007 to 0.017 mg/L, chromium at 0.01 and 0.02 mg/L, and lead at 0.6 mg/L.

Total Uranium
No detectable concentrations of total uranium were found.

5.4.5.2 Surface Water Sampling Results

Surface water analyzed had no detectable contamination in three of the marsh sampling points or upstream in Sawins Pond Brook. Concentrations of 12 ppm TPH and 0.27 pCi/L total uranium were found in marsh sample M-2, and the downstream location of Sawins Pond Brook indicated 73 ppm of TPH and trace di-n-butylphthalate.

5.4.6 CNSI Conclusions

In general, CNSI found that petroleum hydrocarbon levels at the Site, although elevated in some areas, were consistent with results from other upgradient studies. Similar results were found for VOCs and SVOCs, although some VOCs were detected in groundwater, including MTBE, a gasoline additive which was determined to mark the leading edge of a plume from an upgradient gasoline release. Somewhat elevated concentrations of metals were found – including lead, mercury, silver, and zinc. This is similar to nearby sites, and TCLP concentrations were below regulatory levels, except for two instances of cadmium and one of lead. Uranium concentrations in excess of the 35 pCi/g soil concentration levels were found to be present in the burn area, but otherwise the concentration in soils, sediments, and surface- and groundwater were below regulatory limits with one exception which CNSI had previously noted.

CNSI concluded that conditions at the Site posed a health risk through exposure via direct contact with surface soils, due to the presence of petroleum hydrocarbon residues. Groundwater, surface water and sediment in the brook were not found to pose a risk. CNSI specified that remedial efforts should include the removal or abandonment of a UST located immediately north of Building 235, as well as the excavation of a concrete structure on the north side of the Site. Remediation of the burn area should be completed to specifications. Remedial measures might also require excavation to address elevated TPH and metal concentrations. Additional sampling and field surveying should be performed as part of an MCP Phase II effort, and a long term program of protective covering, drainage controls, and groundwater monitoring was recommended.

5.5 HARDING ESE DRAFT SUPPLEMENTAL PHASE II COMPREHENSIVE SITE ASSESSMENT, GSA PROPERTY, WATERTOWN, MASSACHUSETTS, MAY 1996

The purpose of this survey was to evaluate the nature and extent of chemical contamination in environmental media that might have been caused by usage and activities of the U.S. Army and subsequent tenants of the GSA at the Site, pursuant to the MCP. No radiological investigation was conducted (with the exception of waste characterization), and the burn area was not examined. The stated goals of the survey were to:

- evaluate the concentration and extent of chemical contamination in soil and groundwater near the former location of a fuel oil UST and/or associated piping;
- provide additional information about site geology and hydrogeology;
- evaluate whether contaminated media include surface water and sediments;
- evaluate whether any resources and receptors are at significant risk from contamination by completing an MCP Phase II Risk Characterization for the Site using both chemical and radiological data collected at the Site;
- excavate test pits in the northeastern portion of the Site to further characterize magnetic anomalies detected in that area of the Site;
- sample the contents of two partially-buried steel drums located in the northeastern portion of the Site; and
- evaluate whether additional response actions were required at the Site.

Thirty-seven soil borings were completed, focused on seven areas within the Site. These areas included the former UST north of Building 235 (area A on Figure 5-8), the area around CNSI well W-6A (area B), the blackened area northeast of Building 236, which spreads north from W-7A (area C), the area near CNSI soil boring B-19 (area D), the unexplored area on Property 20, between the burn area and the wetlands – around B-16 (area E), and the unexplored area covering most of the pavement surrounding Buildings 234 and 235 (area F), as well as an area at the southwestern edge of the site selected to provide background information (area G). Borings were advanced to between 11 and 16 feet bgs, depending on the presence of the peat layer in the soil samples. Samples were screened for TPH and VOCs, and then select samples were sent for analysis based upon these results and amount of sample recovery. Figure 5-9 shows investigation locations.

Monitoring wells were installed in 5 of the 37 borings advanced on-site, and screened in the fill layer overlying the peat deposit. Groundwater analyses were undertaken for VOCs, SVOCs, TRPH (total recoverable petroleum hydrocarbons), and TAL (target analyte list) metals. Falling/Rising head conductivity tests were conducted at the newly installed wells.

Surface soil sampling was completed at the base of a transformer pole to determine whether surface soil staining in this location was related to the transformer. Surface water and sediment

samples were collected and analyzed for VOCs, SVOCs, TAL Metals, TRPH, and hardness/total organic carbon (TOC).

A water level survey was completed in 19 on-site wells. Groundwater was typically encountered between 1 and 4 feet bgs. Investigation locations were surveyed for elevation and location on the Massachusetts State Plane grid. A Magnetometer survey was also undertaken in an attempt to determine whether further drums were buried in the northeast portion of the Site, after two drums were located on an earlier site visit. The two drums were excavated and sampled. Test trenching was also carried out in the northeast portion of the GSA Property and on Property 20, but no additional drums were found.

5.5.1 Nature and Extent of Contamination

Because much of the contamination is distributed across the Site in fill materials rather than being located in discrete release areas (e.g., groundwater contaminant plumes or areas of soil contamination surrounding a UST, drywell, or leachfield), the following information is organized around detected compounds rather than specific areas of the site.

5.5.2 Soil

Both surface and subsurface soil contamination at the GSA Property primarily consists of TRPH, SVOCs, and metals. TRPH, SVOCs, and metals were detected in many of the soil samples and appear to directly associated with the fill itself rather than a discrete release(s) of contaminants to the fill.

5.5.2.1 Screening Data

Harding ESE submitted between 2 and 5 soil samples from each boring for VOC and TRPH screening analysis in the HLA laboratory in Wakefield, Massachusetts. Detected VOCs include methyl ethyl ketone (MEK; a.k.a., 2-butanone), cis 1,2-dichloroethene (cis 1,2-DCE), 1,1-dichloroethene (1,1-DCE), toluene, ethylbenzene, chlorobenzene, PCE, benzene, xylenes, TCE, and 1,1,1-TCA. The highest detected concentration of any of these compounds was 3,193 µg/kg of toluene in the 4-6 foot interval from MW-104 (Figure 5-9), but most of the detected concentrations were generally less than 1,000 µg/kg.

Many of the soil samples collected from soil borings located in the area north and east of the burn pit area contained detectable VOCs. Samples BS-118 (4-6 and 9-11), BS-119 (0-2 and 11-13), BS-130 (0-2), BS-131 (4-6 and 14-16), MW-103 (2-4 and 6-8), MW-104 (4-6 and 9-11), and MW-105 (9-11) had detectable concentrations of chlorinated solvents and/or BTEX compounds. For comparison, other VOC detections were generally limited to borings BS-102, BS-104, and BS-132 which are all located near Building 235. Sample locations are shown in Figure 5-9.

MEK was detected in 11 of the samples and was the most frequently detected of the non-BTEX compounds. At least one of the soil samples from borings BS-102, BS-105, BS-108, BS-110, BS-113, BS-114, and BS-115 contained detectable concentrations of MEK. These boring locations are all located north and east of Building 235 and within the original security fence.

5.5.2.2 TRPH Concentrations

TRPH were detected in samples collected from five feet below the water table indicating the TRPH is likely associated with the original placement of the fill material rather than a subsequent discrete release to the fill materials. For example, the TRPH concentrations in the 9-11 foot intervals in borings BS-103 (4,590 mg/kg), BS-118 (7,520 mg/kg), MW-105 (13,100 mg/kg), MW-104 (31,800 mg/kg) were all substantially higher than the sample submitted for laboratory analysis from upper intervals within the respective borings. Observation of the soil samples within each boring also indicates that stained and/or oily materials are more typical of the deeper intervals. For comparison, note that all four of the detected TRPH concentrations listed above are greater than the TRPH concentrations detected at locations BS-104 (3,140 mg/kg at 6-8 feet bgs) and BS-101 (1,770 mg/kg at 12-14 feet bgs) whose locations were selected to evaluate petroleum contamination associated with a former underground storage tank and where visual and olfactory evidence of petroleum contamination was also observed.

HLA completed a test trenching and drum excavation program in the northeast portion of the Site. Soils encountered below the water table during the trenching had a petroleum-like odor and sheen in several locations. One of the two drums excavated during the program contained approximately 40 gallons of oil. The laboratory analysis results indicated the oil is similar to motor oil in weight. Acetone and xylenes were detected in the oil at concentrations of 3,200 µg/kg and 1,500 µg/kg, respectively. No chlorinated solvents or other VOCs were detected in the oil. The SVOCs 2-methylnaphthalene, fluorene, and phenanthrene were detected at concentrations of 52,000, 80,000, and 600,000 µg/kg, respectively. No pesticides or PCBs were detected in the oil sample. Lead was detected in the sample at a concentration of 1.6 mg/kg; no other metals were detected in the sample. The oil was not found to be corrosive or reactive (sulfide or cyanide reactivity). The gamma spectroscopy analysis detected potassium-40 at 457 pCi/l but did not detect any other radionuclides. Although these analyses were performed for waste characterization, the presence of an intact drum likely deposited at the Site during the 1940s or 1950s permits a glimpse of what types of chemicals may have been used at the Arsenal and what types of chemicals may or may not have been present in materials used to fill the Site. Petroleum sheens and odors observed during several monitoring well installations and during portions of the test trenching may be the result of the release of oil similar to that found inside the intact drum.

5.5.2.3 SVOC Detection Limits and Matrix Interference

Because of interference from petroleum-related compounds and relatively high concentrations of SVOCs in the soil samples collected from the GSA Property, the practical quantitation limits (PQLs) achieved by the contract laboratory were often higher than the typical contract required quantitation limits (CRQLs). For example, samples from BS-125 had typical PQLs of 10,000 µg/kg for the SVOC analysis which represents a PQL approximately 30 times greater than the typical CRQL of 350 µg/kg. This phenomenon is further discussed in section 5.5.5.1.

5.5.2.4 Metals

Metals were detected in many of the soil samples collected during both the 1990 CNSI and 1994 HLA field investigations. As indicated above, Site soil contamination is integrally related to the fill material itself rather than a discrete release to the fill. One likely source of the fill material is the

former Arsenal operations at the properties currently occupied by the Arsenal Mall and the Army Research Laboratory (ARL-WT). The former Arsenal maintained large foundry, heat treating, sintering, and other metal working furnaces and equipment and probably generated large quantities of debris such as off-spec castings, sand, slag, and heat treating furnace bricks. The increased production scale during World War II potentially led to large quantities of debris. Research performed during preparation of the Preliminary Assessment of the Former Watertown Arsenal (ABB-ES, 1993) indicates that the GSA Property was being filled during the 1940s until about 1950. Fill materials observed during the field investigations at the Site include metal castings, slag, metal cables, yellowish fire brick, concrete rubble, and a variety of glass, brick and man-made fill materials. Given the likely nature of the fill materials, it is not unreasonable to expect to find metals in soil samples collected at the Site.

5.5.3 Groundwater

Most of the contaminants detected at the Site are associated with the fill and were detected in soil and sediment samples. Relatively little groundwater contamination was detected at the Site.

5.5.3.1 VOCs and SVOCs

Low concentrations of VOCs were detected in some of the groundwater monitoring wells sampled. Both the frequency of detection and the number of compounds detected was also relatively low. No SVOCs were detected in groundwater during the 1994 sampling round. Sample locations are shown in Figure 5-9.

5.5.3.2 TRPH

TRPH were detected in groundwater at concentrations up to 82 mg/l during the 1990 groundwater sampling round (CNSI, 1990). TRPH were detected at concentrations ranging from less than 1 mg/l to a maximum of 4 mg/l during the 1994 sampling round. The order of magnitude difference between the results from the two sampling rounds is likely a direct result of the two different sampling techniques used to collect groundwater samples. In 1990, CNSI used bailers or a Waterra foot valve system to purge the wells and/or collect the samples. Based on the groundwater sampling field forms appended to the 1990 CNSI report, sample turbidity in many of the shallow groundwater monitoring wells was high during both purging and sampling. In 1994, HLA used the low flow sampling technique to obtain samples of very low turbidity. In all but two of the 19 wells sampled in 1994, the sample turbidity ranged from 1.5 to 6.2 nephelometric turbidity units (NTUs) (clear to the unaided eye). Sample turbidity in wells MW-105 and WC-10A was approximately 25 NTUs, still relatively clear to the unaided eye. The difference in the analytical results for 1990 and 1994 is probably a direct result of fine soil particles (and TRPH contaminants) entrained in the 1990 groundwater samples.

5.5.3.3 Metals

Both the 1990 (TCLP for the 8 RCRA metals) and 1994 (TAL metals) data indicate that metals concentrations in groundwater are relatively low, with the exception of two groundwater samples collected near the burn pit by MK in 1994. Harding ESE compared the 1990 and 1994 results for the 8 RCRA metals and noted that barium is the only one of the eight RCRA metals frequently detected in both 1990 and 1994 sampling rounds, and that the detected concentrations are similar. Low levels

of mercury detected in five of the wells in 1990 were not detected in 1994. Except for the metals (calcium, iron, magnesium, manganese, potassium, and sodium) commonly dissolved in groundwater, most of the remaining TAL metals were either not detected or detected at relatively low concentrations (ABB-ES, 1996).

The groundwater samples collected from the burn pit area, from MK/SEG monitoring wells at B-25 and B-31, contained levels of lead and silver above the GW3 standard, with B-25 also exceeding GW3 standards for nickel and zinc. The lead detections in B-25 and B-31 were 2.06 and 0.91 mg/L, respectively, well above the GW3 standard for lead of 0.03 mg/L and the Upper Concentration Limit of 0.30 mg/L. Silver was detected at 0.01 mg/L in both wells, above the GW3 standard for silver of 0.007 mg/L. Concentrations of nickel and zinc in B-25 were 0.18 and 0.91 mg/L, respectively, above the GW3 limits for nickel (0.08 mg/L) and zinc (0.9 mg/L).

5.5.4 Surface Water

5.5.4.1 Surface Water Turbidity

HLA collected a total of 11 surface water samples from the Site. The water depth at the sampling locations ranged from 0.2 to 2.4 feet, and the relative lack of water at two of the locations contributed to high sample turbidity. Sample locations SW-006 and SW-013 were collected from shallow channels which had shallow areas of pooled and stagnant water. The action of collecting the sample created turbid conditions, and the measured sample turbidity at each of these two locations was greater than 200 NTUs (instrument range was exceeded). For comparison, sample turbidity at the other nine surface water sampling locations ranged from 4.7 to 95.1 NTUs. The high sample turbidity likely contributes to the relatively high metals concentrations detected in these two surface samples. For an example of the correlation, lead and zinc concentrations in samples SW-006 and SW-013 were typically an order of magnitude (or more) greater than the next highest concentration.

5.5.4.2 VOCs and SVOCs

Relatively low levels of cis 1,2-dichloroethene were detected in three of 11 surface water samples, one of which was located in Sawins Pond Brook. No VOCs were detected in the brook samples collected during the 1990 sampling program. Bis (2-ethylhexyl) phthalate was detected in three of the 11 surface water samples and was the only SVOC detected. In 1990, a trace concentration of di-n-butyl-phthalate was the only SVOC detected in surface water samples. The 1990 surface water sampling program for VOCs and SVOCs was limited to locations SD-002 (formerly US-1) and SD-003 (formerly DS-1).

5.5.4.3 TRPH

TRPH concentrations in surface water samples collected during the 1994 investigation ranged from less than 1 mg/l to 4 mg/l. In 1990, TRPH were detected in marsh sample M-2 and stream sample DS-1 (corresponds to SW-003) at concentrations of 12 and 73 mg/l, respectively. The 1990 surface water sampling program for TRPH was limited to two locations in Sawins Pond Brook and four locations within the wetlands area along the southeast side of the GSA Property.

5.5.4.4 Metals

The 1990 surface water sampling program for metals was limited to two locations in Sawins Pond Brook and four locations within the wetlands area along the southeast side of the GSA Property. Note that the four wetlands sampling locations were not duplicated in 1994 due to dry conditions. Barium, cadmium, lead, and mercury were detected at least one of these four locations in 1990.

5.5.4.5 Hardness

Water hardness as calcium carbonate ($CaCO_3$) was evaluated for each of the 11 surface water samples. Values ranged from 186 to 975 mg/l. The highest value occurred at SD-013 where a silty surface water sample was collected from the wetlands area along the western portion of the property. The remaining values were all less than 418 mg/l.

5.5.5 Sediments

5.5.5.1 Sample Quantitation Limits

Because of interference from petroleum-related compounds, relatively high concentrations of SVOCs in the soil and some sediment samples, and the characteristically high moisture content (typically 75% in silty or leafy samples) of sediment samples collected from the GSA Property, the practical quantitation limits (PQLs) achieved by the contract laboratory were often higher than the typical contract required quantitation limits (CRQLs). For example, sample SD-005 had typical PQLs of 8,300 µg/kg for the SVOC analysis representing a PQL approximately 25 times greater than the typical CRQL of 350 µg/kg. According to the project manager for the contract laboratory, laboratory technicians attempted to use the regular sample volume for the SVOC analyses but were often unable to perform the extraction and analysis because of the high concentrations of organic materials in the samples. Consequently, the sample volume was reduced to perform the analysis and resolve the targeted compound concentrations but with the resulting higher quantitation limits.

5.5.5.2 VOCs and SVOCs

The VOCs 2-butanone, acetone, and methylene chloride were detected in some of the sediment samples at relatively low concentrations. Sample locations are shown in Figure 5-9.

The SVOCs anthracene, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were detected in SD-003 at concentrations between 9,400 and 44,000 µg/kg. Lesser concentrations of some of these VOCs were also detected in SD-001 and SD-007. SD-001 and SD-003 are Sawins Pond Brook locations, and SD-001 is considered the upstream background location. The presence of SVOCs in sediment at this location suggest that the SVOCs originate from municipal storm water runoff and collection.

5.5.5.3 TRPH

TRPH concentrations in the 15 sediment samples ranged from 422 to 32,000 mg/kg, although 11 o f the 15 values were between 2,400 and 6,500 mg/kg. The highest concentration was detected in

sample SD-003 from the area of Sawins Pond Brook where stream water backs up before entering a culvert beneath Greenough Boulevard. The lowest concentrations were detected at SD-006 and SD-008.

5.5.5.4 Metals

Metals including arsenic, cobalt, lead, copper, and nickel were all detected in sediment samples.

5.5.5.5 Total Organic Carbon

Total Organic Carbon (TOC) content was evaluated for each of the 15 sediment samples. Values ranged from 0.5 to 18.1 percent (dry weight basis). The highest values occurred at SD-003, SD-012, SD-013, and SD-014 where samples characteristically contained leaves, twigs, and other decaying organic matter. The lowest values were obtained at SD-001, SD-002, SD-004, SD-008, and SD-011 where samples with greater mineral content (i.e., sandier) were sampled.

5.6 RADIOLOGICAL CHARACTERIZATION AND FINAL SURVEY REPORT, MORRISON KNUDSEN AND SCIENTIFIC ECOLOGY GROUP, INC., JANUARY, 1996

There were five phases to MK/SEG work at the GSA site. In January through July of 1993, remediation and waste removal was conducted at the burn area based on previous characterization. This remediation was halted when it was determined that construction debris beneath the topsoil was contaminated with DU. MK/SEG performed additional investigations in October and November of 1993, including characterization and termination surveys. At NRC's request, additional characterization and termination surveys were performed from August through December of 1994. These additional surveys included the riverbank of the Charles River to determine whether windborne DU deposition had taken place, Property 20 because of elevated surface radiation levels which were measured on the property, and also boundary areas due to uranium concentrations found outside the burn area fence. In 1995, in situ gamma spectroscopy surveys were conducted in boundary areas which had not been previously surveyed in 1994 due to inclement weather, and also in large portions of the interior. The results of these surveys make up an Addendum to the Site Characterization. The final phase of MK/SEG work consisted of documentation of estimates made for background natural uranium and total uranium concentrations at the site. MK/SEG also attempted to estimate maximum concentrations of uranium in groundwater, should the estimated mass of uranium in soil completely solublize. This documentation was submitted as Addendum 2 to the Site Characterization.

Harding ESE believes that areas previously indicated as exceeding soil concentration standards based on the U+d criteria are likely exaggerated and should be viewed with caution. In the MK/SEG surveys, a gamma spectral analysis was employed to measure the amount of residual radioactivity in soil and in water. The Th-234 gamma signal served as an index, or surrogate for U-238, which does not have a suitable gamma signal at concentrations encountered at the GSA site. This alone is appropriate and credible and does not diminish the value of the data collected for determining the concentration of U-238 present in soil. However, the data collected was also used to provide input to an algorithm used to determine whether the radionuclide profile was indicative of DU (essentially pure elemental uranium stripped of U-235 nuclides) or alternatively, indicated the presence of uranium in its natural isotopic ratios in some equilibrium

association with its progeny. At low concentrations of U-238 (i.e., concentrations near background), counting statistics, the natural variability in the background concentrations of U-235, U-238, Th-234, and Ra-226 nuclides, and the variability in the elemental and isotopic purity of DU make the distinction between DU and U+d claimed questionable. The apparent motivation for this attempted distinction was a difference in the soil concentration standard then applicable at the site (DU = 35 pCi/g; U+d = 10 pCi/g). With the possible exception of the area north of the burn area where historical data and information indicate that there may be some deposition of uranium ores or tailings, it is not credible to assume that uranium residues (other than depleted uranium, attributable to past site operations) are present. Further, evaluation of the dose producing potential of the radionuclide mixture actually present on site through the use of a comprehensive dose modeling code eliminates the need for single nuclide concentration limits.

5.6.1 Burn Area Remediation

MK/SEG was originally contracted to complete the remediation of the contaminated areas at the Site. As part of MK/SEG's remediation effort, the burn pit was excavated, as were other areas which had been previously identified as having isolated residual radioactivity in surface soils, including the area around CNSI boring B-13 where CNSI had obtained a sample with 330 pCi/g of uranium, as well as the area surrounding ANL borings 1-S104 and 1-S106. Further information regarding remediation locations was not included in the MK/SEG report. The excavation of the burn pit confirmed that the material in and around the burn pit was 6 inches to 2 feet of topsoil over 5 to 8 feet of construction debris. The flat surface found by CNSI at 8 to 9 feet bgs was apparently made up of large pieces of this debris, which were removed as part of the remediation activities. The debris terminated at an organic peat layer, and the water table lies from 0 to 2 feet beneath the surface, depending on the seasonal conditions. DU was found to be present in the construction debris on top of the peat layer, and excavation was halted because of the large volume of waste being generated and the possibility that the remediation effort might be spreading DU into new areas. A characterization plan to determine the extent of potential contamination at the peat interface was developed.

Th-234 was detected in soils at concentrations consistent with uranium decay products. MK/SEG chose to use Th-234 to calculate DU concentrations using the method included in Appendix F and the relationship where:

$$\text{DU (pCi/g)} = \frac{\text{Th-234 (pCi/g)}}{0.682}$$

Based on this calculation, DU concentrations in soil removed from the burn pit ranged into the thousands of pCi/g, with the upper two feet of soil showing the highest activity. The overlying debris had DU concentrations ranging from 20 to 480 pCi/g, with no activity detected in the peat.

At the end of the excavations, over 37 B-25 Low Specific Activity boxes of radioactive waste (total volume over 3,600 feet^3) had been generated and disposed of offsite.

5.6.2 Site Characterization and Termination Surveys

The initial 1993 field program included overall site characterization including systematic gamma measurements of the site and additional soil samples randomly selected from the entire site grid, a subsurface soil investigation in the burn pit, and termination surveys of the Building 235 Annex, and Building 237. Sediment samples were also taken from two manholes outside Building 235.

As work progressed, it became evident that residual radioactivity in Property 20 exceeded current limits. In addition, the NRC requested additional information about the lateral spread of radioactivity from the burn pit excavation. Significant uranium concentrations were present in the form of chips or particles of uranium both in and around the burn pit area.

As a result of new information, the 1994 field program was implemented. The new program included several radiological surveys. Lateral surveys of the burn pit using core boring were included, as were gamma analysis of water from monitoring wells, direct beta scanning surveys of the controlled area surrounding the burn pit, in situ gamma spectroscopy, and bulk soil sample processing. In the clinker area, new surveys included in situ gamma spectroscopy, beta surface scans in areas previously identified as potentially contaminated by ANL, and surface and subsurface soil sampling. In situ gamma spectroscopy was conducted in the boundary area. It was decided to extend the site security fence, and a boundary survey was performed to confirm that no residual radioactivity existed at the physical perimeter of the site. Soil sampling was done at the Charles riverbank to determine potential windborne deposition from past uranium burning operations. In situ gamma spectroscopy and surface soil sampling were performed at Property 20, and termination surveys of the Building 235 Annex and Building 653 were conducted. A water sample was taken from sewer manhole #147. Radiological data from the 1993, 1994, and 1995 investigations are included in Appendix E.

5.6.3 Instrumentation

A Ludlum Model 2350 Data Logger (M2350) and various detectors were used for the characterization surveys, the final termination surveys of the buildings, and for the off-site gamma exposure rate survey. The M2350 is used to record the measurements during the survey, and then download them to a computer into a database containing all readings. The Data Logger was used in the rate meter mode for gamma exposure rate measurements, and in the scaler mode for direct alpha/beta measurements. It was also used in the scaler mode when scanning for DU chips.

Detector selection was dependent on the survey to be performed. For direct surface measurements, a 100 cm^2 gas-flow proportional detector was used. A 1 inch by 1 inch NaI(Tl) gamma scintillation detector was used for gamma exposure rate measurements. 550 cm^2 gas-flow proportional detector (designed as a floor monitor) was used for scanning the soil for chips of DU.

The data logger was calibrated with a 1 by 1 NaI(Tl) detector for use as a μR meter. The instrument was calibrated with a Cs-137 source from a calibrated radiation field traceable to NIST. Large area gas-flow detectors were calibrated to small diameter, 15 cm^2 Tc-99 sources for direct measurement on surfaces, for scanning surfaces, and for scanning soil for DU chips. Two

sizes of detectors were used for this survey, the nominal 100 cm² detector and the nominal 500 cm² detector. Sources were checked at two or three locations on the detector face to assure uniform sensitivity across the large detector area.

Pancake GM detectors were used occasionally for scanning to locate chips of DU, for frisking workers in and out of the facility, and for release of potentially contaminated equipment. These detectors, used on several types of meters, were also calibrated to the Tc-99 beta sources.

A Canberra Genie-PC Field Gamma Spectroscopy system (the Inspector) was used for the in situ gamma spectrometry measurements. This consisted of a high purity germanium (HPGe) gamma detection system mounted on a tripod so that the detector was one meter above the ground surface. No shielding was used. A battery powered multichannel analyzer system and a portable computer completed the system. Data acquisition and the generation of nuclide concentration reports in the field are controlled by the Genie-PC software on the portable computer. Spectrum files, calibration files, and reports are stored permanently on the hard disk of the portable computer. The system analyzed soil in place without the need for collecting samples for laboratory gamma analysis.

Laboratory instruments consisted of a Canberra Genie-PC Gamma Spectrometer and a Tennelec LB5100 Low Background Counter. The Genie-PC was used for the counting of soil samples. It consisted of an HPGe detector calibrated to one liter water, one liter soil, and one liter concrete rubble geometry's. It was also calibrated for normal air sample geometry. The Tennelec is a low background alpha and beta counter with an automatic sample changer. The detector is a 2.25 inch gas-flow proportional detector with an ultra thin (80 μg/cm²) window. Alpha and beta radiation from samples are measured simultaneously by pulse height discrimination. The detector is guarded by a cosmic radiation guard detector, and detectors are shielded by four inches of clean lead. Backgrounds for this instrument are typically less than 0.1 count per minute for alpha radiation and less than 2 counts per minute for beta radiation.

5.6.4 Site-wide Surveys

A Gamma Exposure Rate Survey was performed on the GSA Property and in the building interiors. Readings were taken with the 1 inch by 1 inch NaI(Tl) gamma scintillation detector one meter above the ground surface on a 15 meter grid, and results were averaged. Figure 5-10 shows the MK/SEG grid layout. These results were used to estimate the average exposure rate and identify those areas which are elevated above the expected values for the Site.

The gamma radiation was determined to be fairly uniform throughout the Site, with elevated areas near the center of the clinker area (grids E-16 through E-20) and near the access road on the southwestern edge of the Site (L-3). Random soil samples showed the source of these elevated readings to be natural radioactivity. The Site as a whole was shown not to be significantly contaminated by the statistical evidence gathered, although areas which exceeded acceptable limits did exist.

Random soil samples were collected at 25 percent of the grid intersections to provide an unbiased estimate of the soil concentrations for the Site. Sample locations are shown on Figure 5-11. Samples were collected at the surface and at 2 feet bgs. These samples were analyzed for gamma

emitting natural radionuclides, and evaluated for DU by measuring Th-234, Ra-226, and U-235. Average concentrations of all nuclides on the Site were found to be generally low, although several samples contained enough uranium to produce a large standard deviation and high variance, indicating that concentrations in some areas may exceed the limits, defined at the time as 35 pCi/g for DU and 10 pCi/g for uranium plus daughters (U+d).

DU concentrations were not found to be significant. The sampling was biased towards fine material, since only the fine soil fraction was analyzed, and DU chipsfall within the medium to coarse fractions. However, all of the samples in which uranium and measurable levels of Th-234 were found (on the surface at grid locations C-17, C-26, C-33, D-28, and F-27, and at 2 feet below the surface at grid location C-33) had values for U+d which exceeded the acceptable values. MK/SEG concluded that the high values were due to natural material based on the presence of Ac-228, a marker for Ra-228, which is a daughter of the Th-232 decay series. Very little thorium or thorium daughters were used at the AMTL site or processed at the GSA site. Thorium crucibles were used at the Arsenal during DU melting operations, but there is no evidence that the crucibles were ever brought to the GSA site. Three of the six samples were part of follow up samples collected where elevated gamma exposure rates were observed. The highest concentration observed in these samples was 22 pCi/g of DU at C-26.

MK/SEG results indicated that DU concentrations are higher on the surface than below 1 foot bgs. Ra-226 and Ra-228, found in some soil samples, are above the normal levels found in the AMTL site vicinity. These naturally occurring nuclides and their daughters appear to be the source of maximum value exposure rates on the Site. *As mentioned above, the method for calculating the presence of DU versus U+d is not reliable. It seems likely that the locations which MK/SEG found to contain U+d above the acceptable values in fact contain only very small quantities of DU. The distinction between DU and U+d was made because of the regulations applied to the acceptable quantities of radiological material at the time of the investigation. A full discussion of this issue occurs in section 5.6.*

5.6.5 Surveys in the Burn Area

At the beginning of the MK/SEG remediation program, the burn pit was an excavated pit, 25 to 30 feet in diameter and 3 to 4 feet deep, probably due to slumpage into the pit and/or swelling of the peat as it hydrated and expansion of the peat with the removal of overburden. MK/SEG excavated to a depth of approximately 10 feet, removing several large pieces of concrete rubble before discontinuing their excavation.

Several different survey methods were used in the burn area. Soil boring and split spoon sampling were performed to quantify radioactivity in deep layers. Gamma analysis was performed on water from monitoring wells. The burn area was scanned for DU chips to find the breadth and depth of chip disposition, and an in situ gamma spectrometry survey was performed to find the average concentration over larger areas (e.g. 100m^2). Near surface soil sampling was carried out to find the levels of residual radioactivity in large volume samples, and a water sample was taken from the burn pit to find the level of residual radioactivity in the standing water in the pit.

5.6.5.1 Soil Borings

Vertical and angled borings were advanced with a drill rig, and samples were collected from the pit bottom and side walls using a hand auger. Burn area boring locations are shown in Figure 5-12. Samples were analyzed for Th-234 using gamma spectral analysis. Samples from burn pit soil boring that had measurable Th-234 activity were sent to a contract laboratory for total uranium analysis. Th-234 concentrations and DU concentrations as calculated from the Th-234 data are included in the chem boxes on Figure 5-12. Further data may be found in Appendix E. If radioactivity was found in the samples, a further boring was to be made at a point two feet further from the pit until a clean boundary could be established.

The initial work consisted of 11 borings. In borings B-21 through B-24, samples of the fill were collected from the augur flight as composites at intervals of 0 to 1 feet, 3 to 5 feet, and 5 to 7 feet. Sampling then proceeded using split spoons to collect a less disturbed sample. The split spoons were driven through the base of the debris layer into the peat, capturing samples of the fill, silt if present, and peat. These borings were twinned, and the 7 to 9 foot interval was sampled in both borings. All samples were analyzed for radioactivity and hazardous materials.

No significant radiological detections were found in the subsurface of the first four borings, so additional borings, B-26, B-27, B-29, and B-30, were drilled. Again, no significant DU was observed. The results also indicated there to be no significant radiological activity within the peat or the silt (when present) between the peat and the fill layers. Monitoring wells were also installed in three borings, B-25, B-28, and B-31.

In order to better characterize the actual volume and tonnage of radiologically impacted soil in the burn area, more soil borings were installed much closer to the burn pit as part of the subsequent 1994 investigation. Both vertical and angled (15 degrees from vertical) borings were advance as close to the pit as practical, 1 to 2 feet. Soil borings were installed at other locations to supplement previous data, and hand augured borings, both vertical and angled, were driven into the bottom and sides of the pit. Ten vertical borings (B-33, B-35, B-37, and B-38 through B-44), three angled borings (B-32, B-34, and B-36), and 12 hand auger borings (P-1 through P-12) were completed.

Seventy-one samples were analyzed for gamma emitting radionuclides. Count time for each analysis was adjusted depending on the sample mass to achieve a minimum detectable activity for Th-234 of less than 5 pCi/g, equivalent to about 21 percent of the soil concentration limit for DU. When small volume samples were counted, the counting time was increased to obtain the required minimum detectable activity (MDA) of 5 pCi/g. This enhanced the sensitivity for the natural activity present in sand, which was added as necessary to supplement the sample size. The background of the natural activity in the sand was multiplied, increasing the observed concentrations of the nuclides. The presence of K-40 and nuclides from uranium decay series, e.g. Ra-226, Pb-214, and Bi-214, at increased values is attributed to the activity of the sand. Elevated concentrations of K-40 in the peat layer compared to off-site background is explained as a result of the addition of sand and increased counting times, as are elevated levels of other naturally occurring nuclides in deeper stratum samples (from greater than 5 feet bgs).

Eighteen samples contained measurable concentrations of Th-234, indicating the presence of DU. The highest calculated DU concentration was 82 pCi/g, at boring B-21. Comparison of the data from several vertical and angled borings did not show significant lateral transfer of the radioactivity from the surface of the pit to the debris which had not been disturbed by the excavation effort. In addition, the subsurface radioactivity, which generally occurred in the 1 to 3 foot range, tended to appear near the burn pit, where there had been more mechanical activity to disturb of the finer surface material, which then worked its way into the rubble boundary layer as the pit material was removed. The data thus seem to suggest that the DU in the fines was being constantly redeposited on the pit's surface in the form of silt as decontamination efforts proceeded.

5.6.5.2 Water Samples in the Burn Area

MK/SEG attempted to sample the water in 4 wells in the burn pit area. Samples were obtained from two of the four wells (B-25 and B-31). One well was damaged to the extent that a sample could not be collected, and a sample could not be retrieved from another well. In addition, the sample of water collected in the burn pit was analyzed by gamma spectroscopy. *All results were less than MDA for Ra-226, Th-234, or U-235. Since radiochemical analysis was not used to analyze the water samples, a measure of caution should be used in correlating Th-234 concentrations to U-238 concentrations. Assumptions valid for establishing correlation between chemical species in soil may not be valid in water samples due to potential variability in the solubility and mobility of different chemical compounds in the same environment. Further discussion of groundwater sampling at the site is included in section 6.1.*

5.6.5.3 DU Chips in the Burn Area – Surface Scanning and Soil Scraping

A survey was also made to determine the extent of DU chip deposition in the burn area. The surface was scanned with the 500 cm^2 large area gas-flow proportional counter. To obtain information about the depth profile of the DU chip distribution, five areas, each about 60 m^2, were scraped in lifts and repeatedly scanned. Three inches were lifted at a time, followed by scans, until the water table was reached, at approximately 12 inches bgs. Scans were thus conducted at 0, 3, 6, and 9 inches bgs. Surface scans were also performed to the north of the burn area fence in the area designated by ANL as Zone V. Figure 5-13 shows the scanned area, as well as DU chip and soil scraping locations.

The scraping to the water table revealed that the DU chips were not confined to the surface layer, making their complete removal impossible without removing the deeper associated fill. The controlled area boundary was expanded from the initial boundary as DU was located outside the radiation exclusion zone rope. Scanning continued until a perimeter 2 meters wide was measured with no detection of chips. The expanded control area is shown on Figure 5-14.

The area believed to contain the largest number of DU chips is the area immediately south of the burn pit. The area, outside of the burn area boundary, having elevated residual radioactivity covers approximately 600 m^2, and approximately 10 percent of it was scraped at 3, 6, 9, and 12 inches. The results of the survey indicated that there are chips at all levels down to a depth of 1 foot in the burn area.

5.6.5.4 In Situ Measurements and Surface Soil Samples

In situ gamma spectroscopy measurements were conducted in and near the burn area. Since the field of view for the in situ measurements covers a larger area, the localized, discreet nature of the DU chips did not produce high readings. Only one survey measurement near the burn area, of 10.3 pCi/g at FS-20, was elevated, and although the reading is for U+d, it seems likely that the cause of the high reading was actually DU, due to the presence of Th-234 at similar concentrations to those found at other locations, FS-21 through FS-25. (Concentrations of DU ranged from 10.5 to 18.7 pCi/g in these locations.) Figure 5-15 shows in situ gamma spectroscopy and surface soil sample locations.

Additional surface soil samples, labeled FS-27 through FS-53, were collected in the burn area in an effort to better define the contaminated area and the radionuclides present. The results of this further sampling indicated that residual radioactivity was mostly concentrated in the area north and east of the burn pit, with minimal deposition in the southern part of the burn pit area. The nuclides which are present provide no evidence of ores or tailings in the area immediately north of the burn pit. Based on a contour map created of the area DU concentrations, (Figure 5-16), MK/SEG established that the area exceeding the upper limit for acceptable DU concentration (35 pCi/g) was approximately 460m². MK/SEG states that the approximate depth of contamination based on soil boring and bulk soil data is 1 meter or less. The soil sample concentrations represented in the contours do not mesh well with DU chip observation data, but this is consistent with the evaluation that the chips are unimportant as contributors to the total DU concentration based on the bulk soil data from the area, described below.

5.6.5.5 Bulk Soil Samples

Bulk soil analysis was performed to evaluate potential contamination in the large portion of the fill which is made up of large debris, including brick, concrete, gravel, and metallic debris. The quantity of DU and other constituents in the larger debris fraction was unknown because coarse materials were removed from the debris samples during MK/SEG's initial fall 1993 field investigation.

Three bulk soil samples were collected from the surface, at 0 to 3.5 inches bgs, and three from 1 to 12 inches bgs. These samples are labeled BS-1 through BS-3 on Figure 5-12. One location, BS-3, was chosen because it was a hot-spot in surface scanning for DU. Each sample was separated into coarse (>1 inch), medium (1/16 to 1 inch), and fine (<1/16 inch) size fractions. The medium and large fractions were then ground to less than ¼ inch, and analyzed for Th-234, Ra-226, Ac-228, and U-235 by gamma spectroscopy. Previous soil samples for analysis at the GSA site screened out DU chips in the process of removing rocks and debris. This biased the results and explained the inconsistency between in situ and lab sample data. DU chips were removed from the bulk soil samples and counted separately. The samples from the upper zones contained the highest concentrations of Th-234, the marker for DU, and the fines fraction from each zone had a higher concentration than the middle and coarse fractions.

The radioactivity present tends to be associated with the fine fraction of the upper soil layer. The majority of the DU chips would be associated with the middle size fraction. MK/SEG explains the presence of DU in the fines fraction by a combination of the presence of some fines in the

originally generated waste, as well as to the oxidation and particle size breakdown of the larger chips. In addition, DU related to the burning process may account for some of the activity in the fines.

5.6.5.6 MK/SEG Conclusions – Burn Area

The burn pit itself is contaminated with DU in the fine particle size fraction. The fine grained contaminated materials appear to have penetrated the walls of the pit, but have not migrated far into the subsurface material below the surface of the pit excavation. Soil boring and hand auger samples suggest that lateral migration from the existing pit surface is less than 1 to 2 feet into the subsurface materials. Based on a lateral migration of 2 feet outside the lip of the pit, approximately 4,000 cubic feet of contaminated soil could be present. Surface soil near the burn pit contains some concentrations of DU to a maximum depth of 3 feet.

5.6.6 Surveys of the Clinker Area

One in situ gamma spectroscopy measurement was conducted in the clinker area, at FS-26. Scanning for DU chips was also performed, as well as soil sampling in scanned zones. Figure 5-15 shows in-situ measurements and soil samples, and Figure 5-14 shows areas scanned, DU chip locations, and radiological boundary areas.

The in situ measurement for the clinker area, taken at FS-26, produced a result of 79 pCi/g DU. This is a large area estimate, representing the average concentration within a radius of 10 meters around the sample location, for a total area of 300 m^2. Based on this result and the number of chips present in the area, MK/SEG states that the zones shown within the radiological boundary areas require remediation. They estimate the area this represents as being approximately 800 m^2. The radiological boundary areas are shown in Figure 5-14.

The NRC requested that all of the ANL-defined Zones II and V be surveyed with proportional counters. A wide area ground level beta radiation survey of the clinker area was then performed, which indicated extensive DU chip deposition. Three controlled area boundaries were established in the clinker area based upon the results of these surveys. Parts of the area contain natural radioactivity, but surface soil sampling and in situ measurements confirmed the presence of elevated concentrations of DU. 16 soil samples were collected in the clinker area, on or just below the surface. These samples are labeled FS-55 through FS-65, and FS-74. Concentrations of DU and U+d in the clinker area as determined by the soil samples and the results of the in situ measurement at FS-26 correlate well. DU was present in an area of approximately 800 to 900 m^2. The depth of DU deposition was not established, but was estimated at 1 foot. Approximately 10,000 $ft.^3$ of soil may contain DU materials DU, assuming the 1 foot depth.

5.6.7 Boundary Area

The discovery of radioactivity outside of fenced areas, primarily at the northern end of the property, towards Property 20, led to a decision to extend the fencing around the Site. To confirm that the proposed fence location would indeed enclose all areas of concern, an in situ gamma spectroscopy survey was conducted at four perimeter locations: 1), inside the fence along Greenough Boulevard; 2), north of the burn area; 3), along the retaining wall, starting near the

burn pit and extending to the north end of the GSA Property; and 4), an irregular area around and near the entrance to the Site. Results did not indicate that elevated concentrations of radiological material were present in the surveyed areas.

5.6.8 Sampling for Windborne Deposition of Radionuclides Off-Site

Soil samples were collected from the 0 to 1 foot interval from 5 locations east of the Site across Greenough Boulevard, and analyzed for several radionuclides, including U-235, K-40, Cs-137, Ac-228, Ra-226, and Th-234. Sampling was performed to address accounts by former Arsenal employees of smoke from DU combustion blowing across the road. No radionuclides associated with the site were detected in any of the samples. In addition, a Public Health Assessment completed by the Agency for Toxic Substances and Disease Registry (ATSDR) in 1995 found there to be no health risk outside the Site boundary due to activities at the GSA site. Relevant portions of this report are included as Appendix G.

5.6.9 Property 20

Property 20 was surveyed using in situ gamma spectroscopy and surface soil sampling. In situ gamma spectroscopy was used to measure the average concentration of gamma emitting nuclides in a large volume of the surface soil, thereby obtaining more representative results than with soil sampling alone. In addition, gamma spectroscopy served to identify the nuclide mixture for each sample. There were 19 in situ survey locations, measuring overlapping areas both near and further away from the known locations of higher exposure rates from August of 1994. Soil samples were collected at each in situ location, and several samples were collected just beyond the estimated boundary of the region previously identified as having residual radioactivity to verify that the area was correctly delineated. Soil samples were analyzed for their radionuclide content, bulk density, and moisture content. Property 20 in situ and soil sampling locations are shown in Figure 5-17. Concentration data resulting from in situ measurements are based on an algorithm which assumes uniform distribution of activity with depth. Since the deposition in this region is believed to be due to dumping and bulldozing, this assumption is not unreasonable. Results were not corrected for changes in bulk density in soil samples, or for changes in soil moisture content in the in situ measurements. For this reason, soil sample results may be biased high or low by less than 12 percent, and in situ measurements are potentially biased low by less than 3 percent.

The survey determined that elevated concentrations of Th-234, U-235 and Ra-226 (DU and U+d) existed within Property 20. The extent of the elevated concentration area was determined to be approximately 15 meters by 45 meters. The radioactive material in this area is estimated to average about 1 meter thick. The volume is thus approximately 675 m^3. MK/SEG suggests, however, that since the residual radioactivity is far from uniform, it is likely that selective remediation of locally elevated spots might lead to a smaller portion of the total volume requiring removal.

5.6.10 Termination Surveys

Alpha/Beta measurements, gamma exposure rate measurements, and smear surveys for removable contamination were taken in the Building 235 Annex, Building 237, the sewer

manholes outside of Building 235, sewer manhole #147, and Building 653. No measurement at any of these locations was over the established limits. Buildings 234 through 237 had previously been surveyed by ANL. The ANL survey consisted of instrument and smear surveys covering approximately 75% of the building interiors. No elevated radiation levels were found. The results of this survey are included in Appendix C. Building 653 had not been previously surveyed, and the Building 235 Annex was used for the staging of waste generated during remediation operations at the site. It was resurveyed in 1995 at the request of the NRC (Letter included in Appendix B-18). It is not clear from the MK/SEG report why Building 237 was resurveyed.

5.6.10.1 Building 235 Annex

Two thousand, five hundred and twenty-two direct alpha/beta measurements were taken in the Building 235 Annex. The highest result was 3,260 dpm/100 cm². All measurements were below NRC guideline values. The MDA for these measurements is 1,370 dpm/100 cm². Six hundred thirty-two removable surface activity samples were collected in the Annex. All results were less than the MDA of 10 dpm/100 cm². 432 gamma exposure rate measurements were made in the Annex. The highest measurement result was 20 μR/h. All measurements were below the established investigation level of 25 μR/h. The Annex was resurveyed in 1994 following the sorting of bulk soil fractions in the Annex during the burn area bulk soil survey. Five hundred direct beta measurements were taken, and all measurements were below NRC guideline values. The highest measurement was 2,105 dpm/100 cm². Thirty additional removable activity samples were taken. All results were less than the MDA of 10 dpm/100 cm².

5.6.10.2 Sewer Manholes

Two sediment samples were collected from the sewer manholes outside Building 235. The samples were not dried due to biological hazard, so the results could not be related to NRC release criteria. The samples were analyzed for gamma emitting nuclides, and one sample showed no activity concentrations. The other sample showed only naturally occurring nuclides. Th-234 was not present above the MDA in either sample, and it was concluded that DU was not present.

In 1994, a water sample was collected from sewer manhole #147, since flowing water precluded the collection of a sediment sample. Analysis of the water sample indicated Th-234 concentrations below the MDA.

5.6.10.3 Building 237

Four hundred ninety-five direct alpha/beta measurements were made in Building 237. The highest result was 1,670 dpm/100 cm², below both NRC guideline values and established investigation levels. The MDA for these measurements is 1,370 dpm/100 cm². One hundred nineteen samples of removable activity were collected in Building 237. All results were less than the MDA of 10 dpm/ 100 cm². One hundred four gamma exposure rate measurements were made in Building 237. The highest measurement result was 12 μR/h, below the established investigation level of 25 μR/h.

5.6.10.4 Building 653

Fifty-seven gamma exposure rate measurements were taken in Building 653. The highest measurement was 19.4 μR/h, below the established investigation level of 25 μR/h. Three hundred sixty-nine direct beta measurements were taken in Building 653. The maximum measurement was 3,798 dpm/100 cm², below NRC guideline values.

5.6.11 Radiological Status after Additional 1995 Survey

In situ gamma spectrometry (ISGS) was used to measure the average concentrations of several nuclides (primarily from DU) at the boundary of the GSA site, and at selected areas of the Site interior and at Property 20. Areas surveyed included portions of the boundary not surveyed in 1994 due to inclement weather, and large portions of the interior which had previously been surveyed for chips and/or non-specific exposure rate. The ISGS reported activities, which were converted to pCi/g of Pa-234m, Th-234, U-235, and Ra-226.

The radiation controlled areas, established in 1994 in the clinker area due to the finding of DU chips, were determined to have generally very low average concentrations of activity by the 1995 in situ gamma spectroscopy surveying. There were two grid measurement locations which were worthy of concern, one due to Ra-226 and Th-234 (F-17-C1 [NE of F-17], where a reading of 10 pCi/g of U+d was obtained), and one due to DU (FS-26, with 49 pCi/g of DU).

The ground within the burn pit shows high activity due to DU. In addition, DU activity around the burn pit fence towards the northwest is more widespread than measured in earlier surveys by other consultants. The elevated values extend towards the boundary fence, but stop about 5 meters away. Along this distinct line of relatively higher intensity it is possible that granite blocks are buried about 8 inches below the old road surface; a granite block was evidently pulled from within the burn pit at the fence, although the conditions surrounding this removal are not available. A fire hydrant lies outside the outer fence line, and beyond the higher activity area.

In the wooded area north of the burn pit, there were a few locations near the Property 20 boundary which show elevated activity. Some locations north of the burn pit fence (around F-28-C1, and F-29-C1) also show elevated activity (although still below the limits) and MK/SEG recommends they be considered for remediation.

Overall, seven locations in the resurveyed area were determined to be above the limit for either DU or U+d. In addition to the two locations described above, there were four exceedances of the U+d limit of 10 pCi/g (at FS-2, with 25 pCi/g; D-25, with 10 pCi/g; D-26, with 20 pCi/g; and D-33-C1, with 17 pCi/g due to Uranium and daughters) and one exceedance of the 35 pCi/g DU limit, with 38.5 pCi/g at G-26-C2.

5.6.12 Determinations of Background Uranium and Total Uranium Activity

Following a meeting in 1997 with the NRC and the State of Massachusetts, GTS Duratek (formerly SEG) calculated both the total background uranium concentration present in the vicinity of the site, and the total uranium activity on-site. These calculations were then included as Addendum 2 to the Radiological Characterization and Final Survey Report.

Based upon a series of spreadsheet calculations using statistics for Ra-226, Ac-228, and Th-234, GTS Duratek found the background concentration of natural uranium in the fill soil to be 2.12 ± 0.64 pCi/g. The estimated mass of natural uranium on the site in the top 1 foot of fill soil is 55.1 kg. The mass of natural uranium in the fill over an average depth of 7 feet is estimated at 380 kg. These calculations apply only to the unpaved portion of the site – no estimate was made for the paved area around Buildings 234 and 235 due to the lack of data.

A calculation of uranium activity on the site was also performed, based on an average concentration over the Site as a whole of 3.45 pCi/g. Assuming that only the top foot of soil is contaminated, the total uranium activity in the soil was calculated at 0.0629 Ci. This includes background. The same calculation for background uranium yields 0.0387 Ci. The net activity of the site above background is thus 0.0242 Ci of uranium, based on the assumption that only the first foot of soil outside of the paved area is contaminated.

6.0 CONCLUSIONS

6.1 POTENTIAL CONTAMINANTS

As previously described, this document and the following findings are based primarily on radiological data and reports prepared by others; Harding ESE has not collected any additional site data during the preparation of this HSA. All reported observations and conclusions are those included in the documents that have been reviewed and, except where noted, do not reflect any additional interpretation by Harding ESE.

There are a number of potential contaminants, both radiological and chemical, at the Site based on knowledge of the site history and the results of the surveys that have been completed.

DU residues from the burning and disposal operations conducted on the property have been determined to be present at the Site. Much of this residual radioactivity is in the form of DU chips, which are relatively low-activity due to their size, low specific activity, and the fact that uranium is strongly self-shielding. In addition, there are DU fines present in the burn pit as well as laterally in the walls of the pit to approximately two feet. Several ANL borings contained radiological materials at their terminal depths 6 feet bgs. These borings were located either in or near the burn area, or at the northern edge of the Site. The burn area borings have likely been disturbed by later excavation (with the exception of 1-S80, which is outside the former burn area fence), and the elevated readings in the northern portion of the site were associated with uranium tailings material rather than depleted uranium. CNSI found no DU residue deeper than 5 feet bgs at B-13, the only DU deposit they found outside the burn area. MK/SEG estimates the maximum depth of DU in the burn area to be three feet.

Uranium tailings from research conducted at the Arsenal in the late 1940s and early 1950s is likely present at the north end of the Site, both on the GSA Property north of the burn area, and in Property 20. MK/SEG concluded that the tailings material likely made up part of the fill, and so could be present throughout the fill layer in the northern portion of the site (where the fill layer is approximately three feet thick). MK/SEG detected elevated radiation levels that they determined were due to tailings material (based on the presence of Ra-226 without accompanying concentrations of Th-234) at only one of their sample locations in Property 20, FS-01. Tailings are indicated by the presence of Ra-226 and uranium daughter products without uranium itself being present in equivalent concentrations. Therefore, it is more likely that any tailings material at Property 20 is limited to a small area. Radiological soil sampling locations are shown in Figure 6-1.

In addition to radiological constituents, a number of chemical constituents are present. If soil removal is required to address radiological contamination, the presence of chemical contaminants could lead to the soil being classified as a mixed waste. In 1993, material excavated from the Burn Area by MK/SEG was classified as a mixed waste based upon the presence of lead above permissible TCLP concentrations. Most of the chemical contaminants detected in soil were likely introduced as constituents of the fill material.

VOCs have been detected in the fill material. The detected VOC compounds include MEK, cis 1,2-DCE, 1,1-DCE, toluene, ethylbenzene, chlorobenzene, PCE, benzene, xylenes, TCE, and 1,1-

TCA. The highest detected concentration of any of these compounds was 3,193 µg/kg of toluene, and detected concentrations were generally less than 1,000 µg/kg. SVOCs, especially PAHs, were also detected in relatively high concentrations in the fill material.

TRPH was also detected in the fill material. Concentrations up to 31,800 mg/kg (in HLA MW-104) were detected, and the locations which returned high concentration measurements were apparently not related to the predicted on-site sources of contamination, including the burn area and the former location of the UST.

Metals were detected in many of the soil samples. Cadmium and lead in particular have been noted above EPA TCLP toxicity levels of concern. Fill materials observed during field investigations include metal castings, slag, metal cables, yellowish fire brick, concrete rubble, and a variety of glass, brick and man-made materials.

A drum excavated during the Harding ESE survey program contained approximately 40 gallons of oil. The laboratory analysis results indicated the oil is similar to motor oil in weight. Acetone and xylenes were detected in the oil at concentrations of 3,200 µg/kg and 1,500 µg/kg, respectively. No chlorinated solvents or other VOCs were detected in the oil. The SVOCs 2-methylnaphthalene, fluorene, and phenanthrene were detected at concentrations of 52,000, 80,000, and 600,000 µg/kg, respectively. No pesticides or PCBs were detected in the oil sample. Lead was detected in the sample at a concentration of 1.6 mg/kg; no other metals were detected in the sample. The oil was not found to be corrosive or reactive (sulfide or cyanide reactivity).

The results of groundwater investigations conducted at the site do not indicate radiological contamination of groundwater at the Site. All results of groundwater radiological analyses conducted by CNSI and MK at the Site were below levels of concern. Chemical analyses of groundwater indicated low concentrations of VOCs and metals. The only SVOC detected in groundwater sampling was naphthalene in one sample in 1990. TRPH was detected at up to 4 mg/L by low flow sampling in 1994.

6.2 POTENTIAL CONTAMINATED AREAS

6.2.1 Impacted Areas – Known and Potential

The burn area is known to be impacted by the deposition at residual concentrations of DU. Fine material containing uranium is concentrated at the bottom of the pit, and has also penetrated the sites of the pit to a distance of up to 2 feet. In addition, there are DU chips present on the surface surrounding the burn pit, and scraping conducted by MK/SEG and described in their 1996 report revealed that the chips are present in the fill to at least 1 foot bgs. Material removed from the burn area by MK/SEG in 1993 was categorized as mixed waste due to the high lead concentrations present in this material.

There are three zones in the clinker area (in addition to the enlarged burn area) which have been cordoned off because of their elevated (above background) radiological readings. Background data gathered by MK/SEG is included in Appendix E. These areas have large numbers of DU chips in addition to elevated surface soil sample analysis results for DU and U+d, and elevated in

situ gamma spectroscopy measurements. The total area affected is approximately 900 M^2 (MK/SEG, 1996).

Areas north of the burn area, including a portion of Property 20, are believed to contain deposits of DU and uranium tailings. In addition, elevated concentrations of Th-234 (a tracer for DU), U-235 and Ra-226 (DU and U+d) were found in the area. This area is approximately 675 m^3. The residual radioactive material is believed to be part of the fill material in this area, and so the depth of elevated radiological concentrations could be up to the fill thickness, approximately three feet bgs. (MK/SEG, 1996). Areas which have been found to have elevated levels of DU or U+d are shown in Figure 6-2.

6.2.2 Non-Impacted Areas

No radiological material has been found offsite, and surveys have shown the area outside the perimeter fence to be free of elevated residual radioactivity. This includes the paved area as well as the exteriors and interiors of Buildings 234, 235, 236 and 653. Building 237, located within the clinker area, has also been found to be uncontaminated based on building surveys.

It is likely that buildings 234, 235, and 236 were constructed in the late 1940s, and certainly before 1952. As DU burning is believed to have begun in 1955, and possibly as late as 1959, the fill material beneath the paved area would not reasonably be considered as potentially impacted by DU burning operations. Although uranium tailings are present at the GSA Property from research conducted in the late 1940s and early 1950s, the tailings have only been found at the far northern end of the Site. Filling of the site around the buildings was likely completed long before this period. The soil and fill material located beneath Buildings 234, 235, and 236 is therefore likely to be unimpacted.

6.3 POTENTIAL CONTAMINATED MEDIA

Potentially contaminated media at the Site include surface and subsurface soil and groundwater.

6.3.1 Soil

Residual radioactivity in the form of DU chips, as well as fine material containing DU, uranium ores, and tailings exists in the soil at various parts of the Site. Residual radioactivity has been found in soils to depths of up to 6 feet by ANL in and near the burn area, and in the northern portion of the site. Residual radioactivity was found by CNSI to a depth of 8-9 feet in the burn area. Two soil borings in the fill material in the northern portion of the Site were found by ANL to contain tailings material, and one MK/SEG boring on Property 20 was also found to contain uranium tailings material. Several areas in the clinker area were cordoned off by MK/SEG due to the presence of radionuclides at the surface, including DU chips (Figure 6-2).

6.3.2 Groundwater

Several of the investigations, including ANL, CNSI, and MK/SEG conducted radiological groundwater sampling. All monitoring wells installed at the GSA Property are shown in Figure 6-3.

ANL conducted their groundwater sampling out of open boreholes. Groundwater was collected from boring numbers B-86, B-90, B-91, B-92, B-93, and B-95. Of these samples, none were judged to contain elevated radionuclide concentrations in the dissolved solids fraction. However, 1-W86 (from boring B-86) and 1-W91 (boring B-91) were judged to contain elevated levels of radionuclides in the suspended solids fraction. These concentrations were 55 pCi/g in 1-W86 and 4.7 pCi/g in 1-W91. The presence of elevated radiation in the suspended solids fraction is not necessarily indicative of the presence of radionuclides in the groundwater, since the samples were not collected from properly installed monitoring wells. The suspended solids fractions of these samples would likely contain soil particles from the borings which would not ordinarily be subject to transport by groundwater. The soil samples collected in borings 1-S86 and 1-S91 had uranium fluorometric measurements up to 242 pCi/g and 7.9 pCi/g, respectively.

CNSI installed 11 shallow and four deep monitoring wells, from which groundwater samples were later collected and analyzed for total uranium. The shallow monitoring wells were generally set from 11 to 14 feet bgs, with 10 feet of screen. MW-4A was only 8 feet deep with 7 feet of screen. The deep wells were set approximately 50 feet deep with 10 feet of screen. Three well volumes were purged prior to the collection of groundwater samples from the CNSI wells. Samples were collected either with Waterra pumps (dedicated tubing and check-valves) or with bailers. Only four of the 15 wells had detectable concentrations of total uranium. Wells MW-7A, -8A, and -9A all had concentrations of 0.27 pCi/L, and well MW-1B had a concentration of 0.34 pCi/L. These concentrations are well below all regulatory guidelines and are consistent with typical background. In addition, wells MW-7A, -8A, and -9A are all located a significant distance from the burn area, and from any known potential source areas of uranium, and MW-1B is located upgradient of the burn area. Shallow wells MW-3A and MW-4A are located downgradient of the burn area and are screened above the peat. No uranium was detected in any of these locations.

MK collected two groundwater samples from wells located in the Burn Area, at borings B-25 and B-31. These wells are approximately 10 feet deep, with nine feet of screen, and were completed above the peat. Groundwater samples were collected by bailer after purging three well volumes, and apparently were not filtered. Analytical results showed no activity above the minimum detectable activity. However, these two wells were upgradient (west) of the burn pit.

Wells installed on the Site have typically been screened over a ten foot interval, which in some cases extends into the peat layer. Radionuclides have typically been detected on the surface or in the fill material above the peat layer. Due to the nature of the peat, it is highly unlikely that any radionuclides would have penetrated this zone. It is likely that radionuclides present at significant concentrations in groundwater above the peat layer would have been detected with 10 foot screens set within the fill layer.

ABB Environmental Services (ABB-ES), 1993. Former Watertown Arsenal Preliminary Assessment, Watertown, Massachusetts. Prepared for COE-NED, October 1993.

ABB-ES, 1996. Draft Supplemental Phase II Comprehensive Site Assessment, GSA Property, Watertown, Massachusetts. Prepared for COE-NED, May 1996.

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APPENDIX A

AERIAL PHOTOGRAPHS

Index to Aerial Photographs

1938 - National Archives
1951 - Massachusetts Highway Department
1952 - National Archives
1962 - National Archives
1968 - Oblique Helicopter Survey for WRA
1969 - Massachusetts Highway Department
1974 - Watertown Public Library (Two Photographs)

APPENDIX B

ASSORTED DOCUMENTS FROM THE NUCLEAR REGULATORY COMMISSION

B-1: Arsenal GSA History as Compiled by the NRC
B-2: Letter, December 22, 1966, Including Approximate Date of DU Incineration Commencement
B-3: Letter, Docketed December 5, 1966, Describing Process of DU Incineration
B-4: AEC License Compliance Inspection Report, Dated September 16, 1965
B-5: AEC License Number SUB-238, Dated May 9, 1961
B-6: Letter, November 19, 1973, Including Results of Radiation Safety Survey of 1973
B-7: Letter, June 9, 1973
B-8: Letter, September 19, 1967, Including Results from 1967 Radiological Survey
B-9: Letter, October 12, 1967
B-10: Letter, March 8, 1973
B-11: AMMRC Survey Report, Dated January 18, 1973
B-12: Letter, March 20, 1973
B-13: Letter, May 15, 1973, Including Decontamination Guidelines of April 22, 1970
B-14: Letter, July 15, 1992, Including Comparison of ANL and CNSI Surveys
B-15: Letter, February 22, 1993
B-16: Letter, March 18, 1993
B-17: Letter, April 7, 1993
B-18: Thorium Crucible Discussions

APPENDIX C

ARGONNE NATIONAL LABORATORY DATA

APPENDIX D

CHEM-NUCLEAR SYSTEMS, INC. DATA

APPENDIX E

MORRISON KNUDSEN & SCIENTIFIC ECOLOGY GROUP (MS & SEG) DATA, JANUARY, 1996

APPENDIX F

MK & SEG: METHOD FOR CALCULATING DEPLETED URANIUM OR URANIUM PLUS DAUGHTERS BASED ON TH-234, RA-226, AND U-235, FROM APPENDIX J OF THE MK/SEG REPORT OF JANUARY, 1996

APPENDIX G

ATSDR PUBLIC HEALTH ASSESSMENT
(SELECTED PAGES)