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IAAAP AERIAL RADIOLOGICAL SURVEY

DRAFT FINAL

Prepared for

U.S. Army Joint Munitions Command
Rock Island, IL 61299-6000

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EXECUTIVE SUMMARY

An aerial measurement system (AMS) survey was performed under the ER,A Program for the Iowa Army Ammunition Plant (IAAAP) located near Burlington, Iowa between October 23, 2002 and October 29, 2002. Gamma ray spectra from both natural and man-made sources were collected for the entire IAAAP site and a portion of the surrounding community using a sodium iodide detector system mounted on a helicopter flying at 60 knots at an elevation of 100 ft. Overlapping flight pathlines separated by 200 ft were followed in the survey; 50,333 data points were recorded. Gross-count data, reflective of gamma ray emissions from all sources (both natural and man-made) recorded during the survey ranged from about 1,700 to 68,000 cps. The mean gross-count rate was about 9,200 cps, with a statistical standard deviation of the count rate of approximately 1,500 cps. Highest gross counts coincided with Yard E, the coal pile, and Firing Site 12. No off-post high gross counts were detected. Man-made gross counts, reflective of gamma ray emissions from only anthropogenic sources, were also evaluated for the study. The man-made gross counts ranged from about -1,800 to 32,260 cps, with a mean count rate of about 26 cps. The standard deviation of the man-made gross counts was about 555 cps. The highest man-made gross counts were recorded for Yard E, the coal pile, and Firing Site 12. The high count rates observed in Yard E are associated with a gamma-ray spectrum with strong ^{234m}Pa photopeaks, which is consistent with the known storage of depleted uranium (DU) materials in Yard E buildings. The high count rates observed over the coal pile show a strong ^{214}Bi photopeak, which indicates the presence of natural uranium in the coal. The elevated count rate at Firing Site 12 is much weaker than the other sites and the statistics of the measurement do not permit a definitive identification of the radioisotope, but the spectrum is consistent with DU.

NOMENCLATURE

Acronyms and Abbreviations

The following is a list of the acronyms and abbreviations (including units of measure) used in this report. Notation used only in certain equations and tables is defined in the respective equations and tables.

AEC	Atomic Energy Commission
AMS	Aerial Measurement System
ADC	Analog-to-digital converter
AGL	Above ground level
BAECP	Burlington Atomic Energy Commission Plant
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	Contaminant of potential concern
DGPS	Differential global positioning system
DNT	Dinitrotoluene
DOE	U.S. Department of Energy
DU	Depleted uranium
EDA	Explosive Disposal Area
ER,A	Environmental Restoration, Army
FS	Firing Site
FUSRAP	Formerly Utilized Sites Remedial Action Program
GC	Gross counts
GIS	Geographical information system
GPS	Global positioning system
HMX	High Melting Point Explosive
IAAAP	Iowa Army Ammunition Plant
IOP	Iowa Ordnance Plant
K_{MM}	Ratio of low-energy counts to high-energy counts in the reference region of the survey
LAP	Load, assemble, and pack
MDA	Minimum detectable activity
MMGC	Man-made gross counts
NaI	Sodium iodide
NCRP	National Council on Radiation Protection and Measurements
NRC	Nuclear Regulatory Commission
NU	Natural uranium
PA	Preliminary Assessment
PIC	Pressurized Ionization Chamber
PRG	Preliminary Remediation Goal
RDGPS	Real-time differential global positioning system

RDX	Royal Demolition Explosive
REDAC	Radiation and Environmental Data Analyzer and Computer
REDAR	Radiation and Environmental Data Acquisition and Recorder
RSL	Remote Sensing Laboratory
SVOC	Semi-Volatile Organic Compound
TNT	Trinitrotoluene
USACE	U.S. Army Corps of Engineers
VOC	Volatile Organic Compound

Units of Measure

Bq	becquerel(s)
Ci	curie(s)
ΦCi	microcurie(s)
cps	count(s) per second
°F	degree(s) Fahrenheit
eV	electron volts
ft	foot (feet)
gal	gallon(s)
Gy	gray(s)
h	hour(s)
in	inch(es)
keV	kiloelectron volt(s)
kg	kilogram(s)
lb	pound
L	liter(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mCi	millicurie(s)
mi	mile(s)
mi^2	square mile(s)
mm	millimeter(s)
mph	mile(s) per hour
pCi	picocurie(s)
R	roentgen(s)
ΦR	microroentgen(s)
rad	radiation absorbed dose
rem	Roentgen-equivalent man
s	second(s)
yr	year(s)

Chapter 1 Introduction and Operational History

The Iowa Army Ammunition Plant (IAAAP) is a secured, operational facility that is located on about 19,000 acres (about 30 mi^2) in rural Des Moines County, Iowa near Middletown, Iowa. The facility is located about 6 mi west of Burlington, Iowa (Figure 1-1). Since 1941, IAAAP's primary mission has been to load, assemble, and pack (LAP) a variety of conventional ammunition and fusing systems. Less than a third of the IAAAP's property is occupied by active or formerly-active production or storage facilities (ATSDR 2003).

The site contractor, Mason & Hanger-Silas Mason Co., Inc., was issued Nuclear Regulatory Commission (NRC) Source Material License SUC-1381 authorizing possession of depleted uranium (DU) in solid form. This license was terminated and then reissued as Iowa Department of Public Health License 0290-1-29-SM1, which was issued to American Ordnance, LLC (who replaced Mason & Hangar-Silas Co., Inc.) on April 13, 2000. This license authorizes assembly and demilitarization of DU penetrators (armor-piercing ordnance) in munition assemblies and for performing research and development as described in the application to the Nuclear Regulatory Commission (NRC) dated October 6, 1993.

All IAAAP land is currently owned and under the control of the U.S. Army. Portions of the facility were previously under the control of other tenant organizations, including the Atomic Energy Commission (AEC). The AEC used approximately 1,900 acres of the site from 1947 to 1975. The areas occupied by the AEC became known as the Burlington Atomic Energy Commission Plant (BAECP). This use created the potential for radioactive contamination. Additionally, some areas of the facility have been transferred to outside entities and are no longer under the control of the Army. These excessed areas include former residential areas that are not expected to have been impacted by AEC activities. Approximately 7,750 acres are currently leased for agricultural use, 7,500 acres are forested, and the remaining areas are used for administrative and industrial operations.

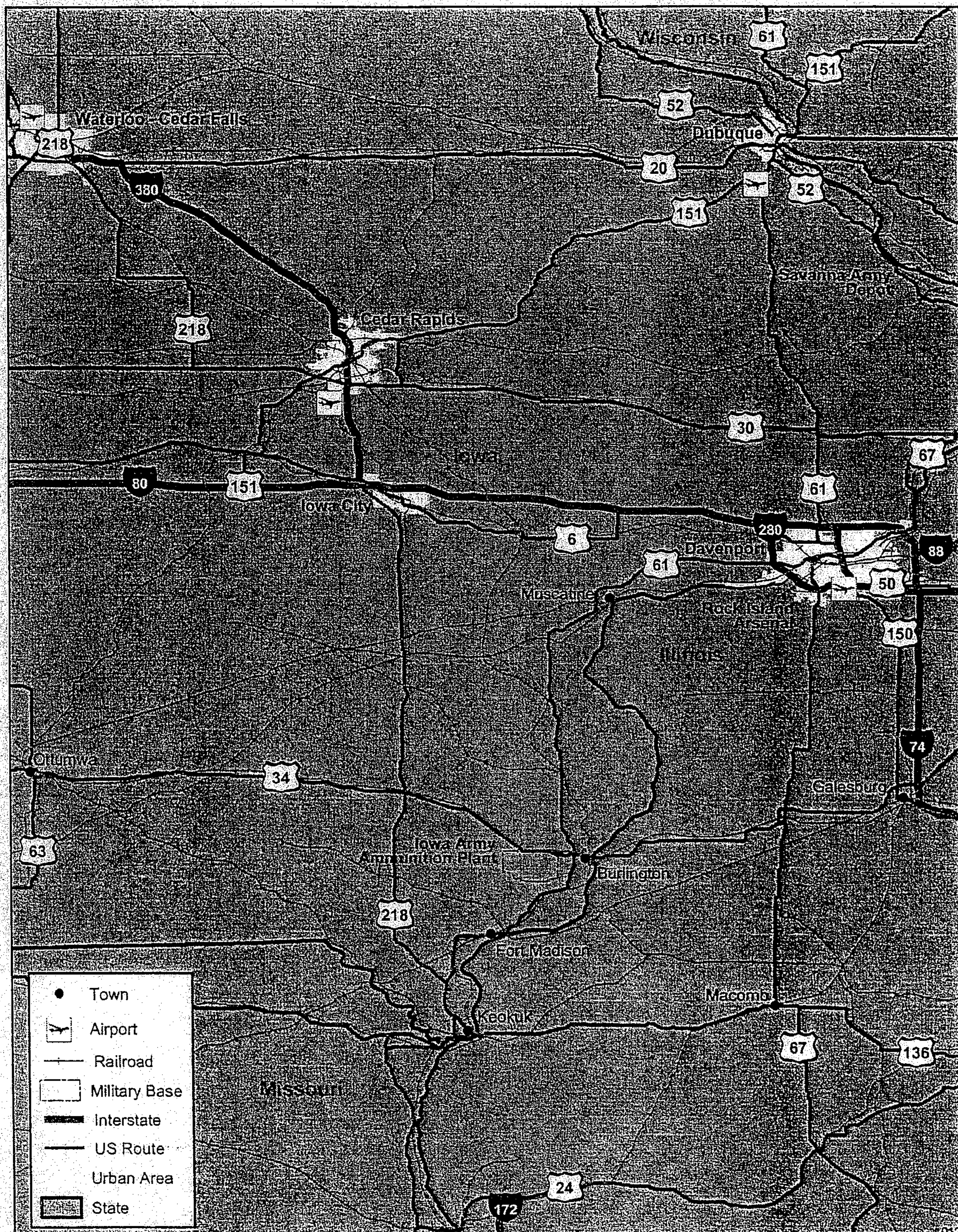


Figure 1-1 Iowa Army Ammunition Plant (IAAAP).

Construction of the IAAAP facility began in early 1941 and was completed in February 1942. At that time, the plant was known as the Iowa Ordnance Plant (IOP). Day and Zimmerman Company, Inc. operated the plant. The Army produced the first ordnance items in the fall of 1941. Between the start and end of World War II, the plant produced 75- to 155-mm artillery projectiles and 100- to 1,000-lb bombs. Production of ammunition halted in August 1945. The plant, which was reverted to a government owned and operated facility, was put to use storing and demilitarizing large quantities of ammunition.

In 1947, IOP was selected as the first production facility for manufacturing high explosive components for weapons under the AEC. A portion of Line 1, the Explosive Disposal Area (EDA) sites, Yards C, G, and L, the Firing Site (FS) areas, and other areas as described below, came under the control of the AEC and its contractor, Silas Mason Company (later known as Mason & Hanger-Silas Mason Co., Inc.) (Figures 1-2 and 1-3).

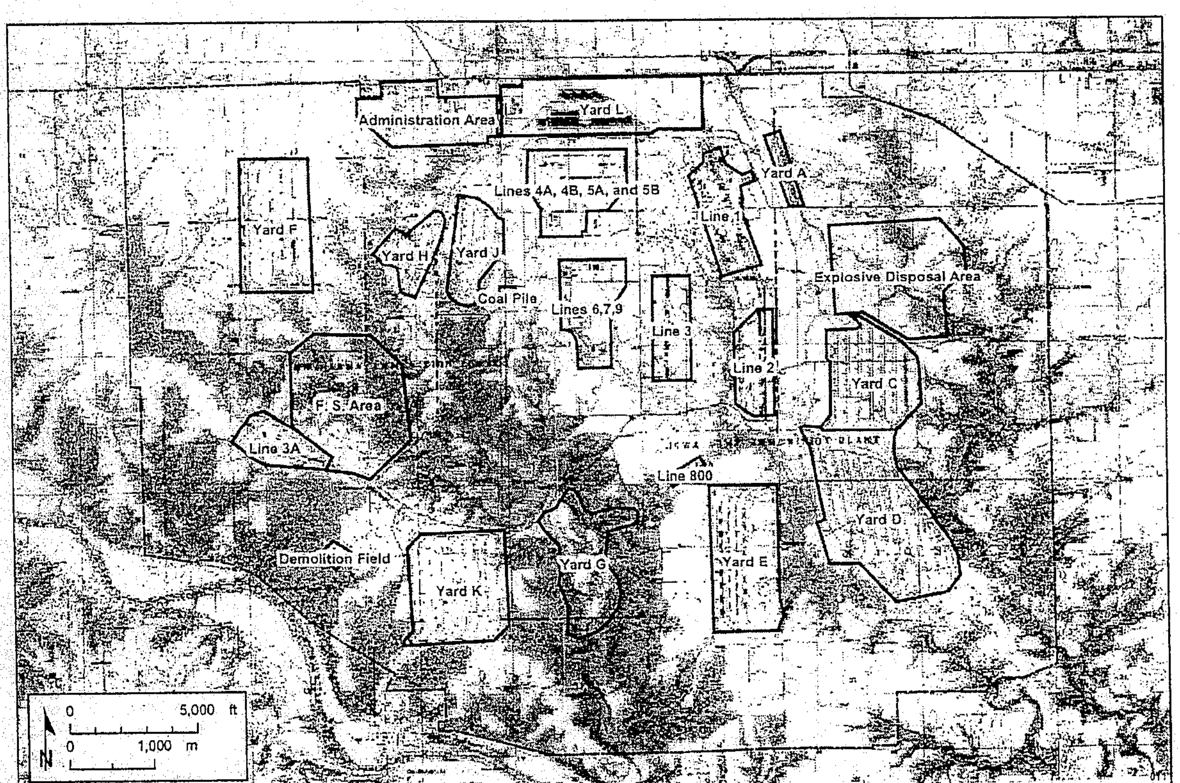


Figure 1-2 Physical layout for IAAAP.

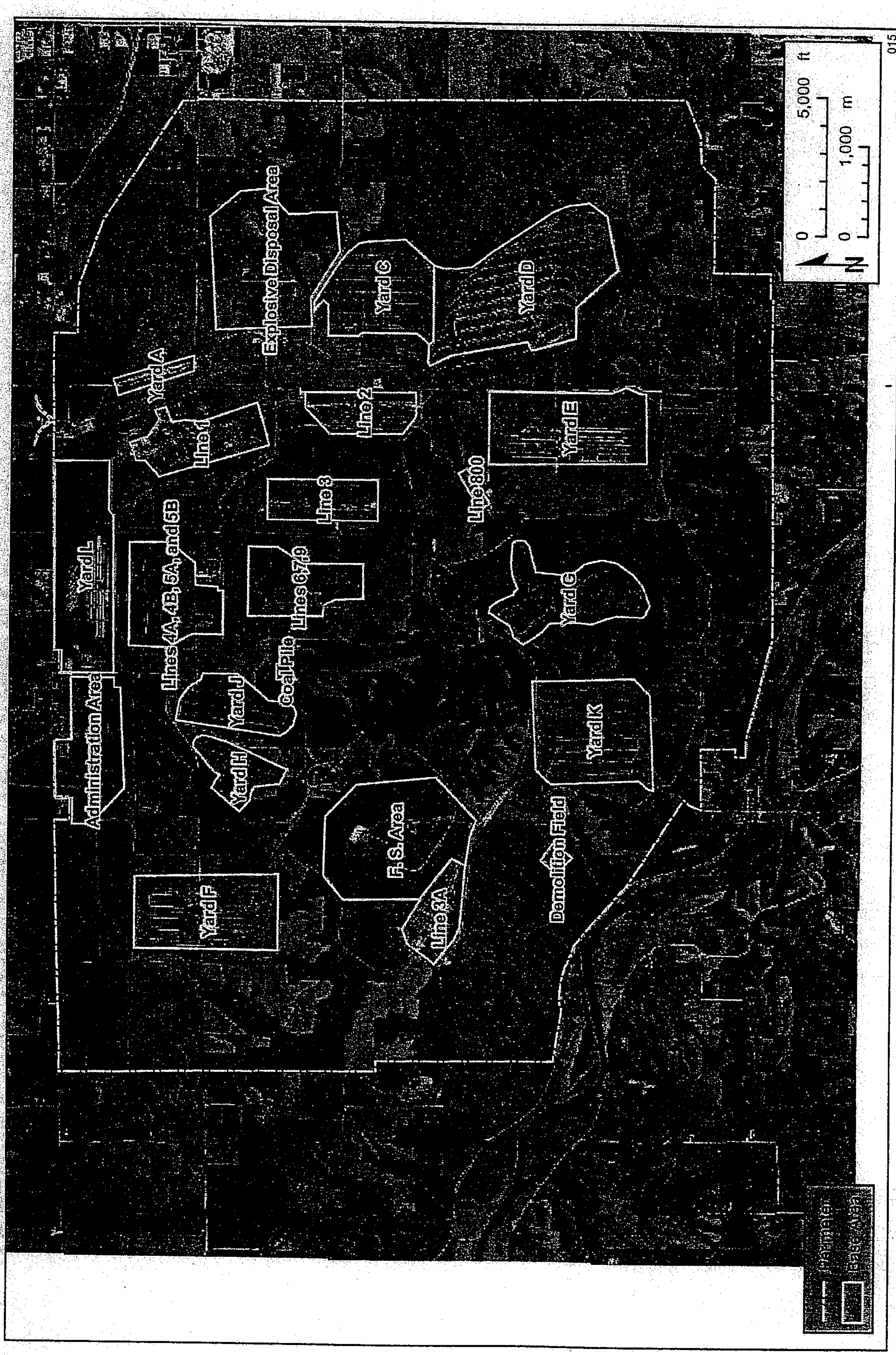


Figure 1-3 Aerial photo of IAAAP.

In the late 1960s, AEC operations at the BAECP were phased out and consolidated at the Pantex Plant near Amarillo, Texas. The BAECP closed in July 1975, and control of the areas reverted to the IOP under the direction of the Army. Later, the plant name was changed from the IOP to IAAAP.

Wastes produced at IAAAP by past Army and AEC activities consist of various explosive-containing sludges, wastewater, and solids; lead-containing sludges; ashes from incineration and open burning of explosives; waste solvent from industrial and laboratory operations; waste pesticides; radioactive wastes; and incendiaries (EPA 2003). The explosives include trinitrotoluene (TNT), dinitrotoluene (DNT), and cyclomethylenetrinitramine (RDX).

Due to the nature of the AEC operations, little information is currently available on past Line 1 activities. It is known, however, that nuclear weapons were assembled at Line 1 using several high explosives and that radioactive materials were received in a sealed configuration and were swipe tested for leaks before use (ATSDR 2003). A Preliminary Assessment (PA) performed by the St. Louis District of the USACE indicated eight areas that were potentially contaminated with radioactivity. The eight areas include the following:

1. Firing Sites 6 and 12,
2. Line 1 Former Impoundment Area,
3. Storage yards C, G, and L,
4. Explosives Disposal Area (EDA),
5. Inert Disposal Area,
6. North Burn Pads Landfill,
7. Deactivation Furnace, and
8. Line 3 Warehouse 301.

For the IAAAP AMS survey, portions of the off-post area are also under consideration for radioactive contamination.

The purpose of the AMS radiological survey is designed to achieve the following objectives:

1. Examine IAAAP and a portion off-site to delineate any remaining contaminated areas that must be addressed under FUSRAP, rather than the Environmental Restoration, Army (ER,A) account,
2. Within the detection capabilities of the radiological instrumentation, ensure that there is no contamination in areas that are thought to be free of contamination, and
3. Provide information for further site assessments by FUSRAP and ER,A.

Constituents of potential concern (COPC) include DU (primarily ^{238}U), radium-226 (^{226}Ra), plutonium-239 (^{239}Pu), and associated fission products. Cesium-137 (^{137}Cs) was used as an indicator of long-lived fission products.

Chapter 2 Environmental Setting

The following sections discuss climate, topography, soil, land use surface water, and groundwater.

2.1 Climate

IAAAP has a mean temperature of 51.8 °F. The average annual precipitation is 40.61 inches. This precipitation is well distributed throughout the year. Southeast Iowa is wetter and warmer than most of the State of Iowa. Winters are generally mild, with infrequent heavy snows. Ice storms are common, with one or two destructive storms occurring yearly. Spring comes fairly early, with the potential for frost lasting through the middle of April. March is the windiest month of the year; May and June are the wettest. Thunderstorms are frequent, especially in June and July, with one storm occurring every three days on average. Thunderstorms occur on an average of 55 days per year.

2.2 Topography and Soil

The topography of the area surrounding the IAAAP is characterized as a natural prairie and is currently used as farmland. The northern section of the site has gently undulating terrain. The central portion is characterized by rolling terrain dissected by a shallow drainage system. The southern portion of the site contains drainage ways with steep slopes down to creek beds. The IAAAP area terrain ranges from flat (60%) to hilly and rough (40%) (Figure 1-2). Elevation at IAAAP ranges from 530 ft above mean sea level in the south to 730 ft above mean sea level in the north.

Soils at the IAAAP have been contaminated by past activities. The primary source of contamination at the site is attributable to past operating practices in which explosive-contaminated wastewater and sludge were discharged to uncontrolled, on-site lagoons and impoundments. Contaminants for which preliminary remediation goals (PRGs) were established include the following: antimony, arsenic, beryllium, lead, thallium, benzo(a)pyrene, 1,3,5-trinitrobenzene, 2,4,6-TNT, RDX, HMX, actinium 228, bismuth 214, and potassium 40 (USAEC 1997.)

2.3 Land Use

IAAAP is located in rural Des Moines County, Iowa near Middletown, Iowa, about 6 mi west of Burlington, Iowa. In 2000, the population of Burlington was 26,839. The population for Middletown, Iowa in 2000 was 535 (Iowa State University 2003).

Land use on the IAAAP property consists of administrative and industrial operations (approximately 4,000 acres), leased agricultural use (approximately 7,750 acres), and forested land (approximately 7,500 acres). Some pasturing of cattle takes place in munition storage yards (ATSDR 2003). Crops grown in the area consist mostly of corn and soy beans.

Public access to the installation is restricted by contractor security measures, including perimeter fencing, but various recreational activities are allowed in some non-industrial, on-site areas. These recreational activities include hunting and fishing. Public access to many on-site contaminated areas, however, is prevented by secondary fencing surrounding installation facilities and industrial areas.

2.4 Surface Water

Several streams, rivers, and other surface water features occur on IAAAP property. The primary watersheds draining IAAAP are Brush Creek, Long Creek, and Spring Creek. The Skunk River flows near the southern boundary of the facility. A small unnamed tributary that flows directly into Skunk River drains a small part of the southwestern sector of IAAAP. These four streams divide the facility into four drainage basins that generally trend northwest to southeast. A small area in the northern portion of IAAAP drains into Flint Creek; another small watershed on the northern portion of the installation drains into Little Flint Creek and impacts the Yard L Area. These watersheds are classified by the Iowa Water Quality Standards as Class B(w) waters, indicating that they provide warm water suitable for wildlife, fish, aquatic and semiaquatic life, and secondary water uses. An additional thirty ponds and small impoundments, totaling approximately 13 acres, are located on the installation (ATSDR 2003).

Brush Creek flows from IAAAP's northern boundary, through the central part of the base, down to the southeastern corner of the property. It passes through the locations where most activity associated with facility operations occurs, draining the majority of industrial operations: Lines 1, 2, 3, 6, 7, 9, 800, the Line 800 Pinkwater Lagoon, the former Line 1 Impoundment, parts of Lines 4A and 5A, the Pesticide Pit, and the Sewage Treatment Plant. Long Creek flows east from IAAAP's western boundary into Mathes Lake (formerly known as Long Lake), which is located in the central part of the installation. Long Creek surface waters remain uncontaminated. Until 1977, treated surface water from Mathes Lake served as IAAAP's primary drinking water source. Spring Creek flows south along the installation's eastern boundary. RDX is a primary contaminant of concern in the creeks, although other explosives and some metals have been detected in Brush and Spring Creeks. ATSDR concluded that past exposures to on- and off-site surface water pose an indeterminate public health hazard (ATSDR 2003).

Currently, public exposure to contaminated surface waters (i.e, surface waters that fail to meet ATSDR's drinking water comparison values and health advisory levels) is extremely limited, if it occurs at all (ATSDR 2003). The primary contaminant in surface water is RDX, with other explosives (including TNT) detected in trace amounts. Contaminant concentrations, especially those detected in Brush Creek, fluctuate and have not been fully characterized.

There are several water-related recreational facilities on IAAAP and in the immediate area surrounding the installation, but none of these recreational facilities have been affected by contaminated surface waters (ATSDR 2003). A boat ramp is located on the east shore of Mathes Lake that is used by fishermen, the Skunk River is located south of IAAAP and has two boat launch access areas and one small park located on its banks. The Skunk River is used for many forms of recreation including boating, swimming, and fishing. Brush Creek is too small to be suitable for typical recreational activities such as swimming, boating, or fishing, but it may be used for recreational purposes by children. Children only have access to Brush Creek after it leaves IAAAP property (ATSDR 2003).

2.5 Groundwater

Two main aquifers are present beneath the IAAAP: the loess/till aquifer (drift aquifer); and the underlying upper bedrock aquifer (ATSDR 2003). The groundwater table in the drift aquifer (elevation of the top of the groundwater aquifer) generally occurs within 10 feet of the ground surface. Shallow groundwater flow closely parallels the ground surface. Thus, shallow groundwater flow throughout the facility is from high points, including most of the Line and Yard areas, toward surface drainages, particularly the larger streams such as Spring, Brush, and Long Creeks and the Skunk River. The water in the upper bedrock aquifer generally flows to the south and east, toward the Skunk and Mississippi Rivers. In some on-site areas, including the southwestern part of IAAAP, the upper bedrock aquifer is exposed at the ground surface and groundwater discharges into surface waters. Elsewhere at IAAAP, the upper bedrock aquifer lies at depths of more than 50 or 100 feet.

IAAAP has five on-site production wells, none of which have ever been used for drinking water purposes (ATSDR 2003). Four of these five wells were installed in 1941 and remained functional until 1977, when IAAAP began using public water from the City of Burlington. Three of these on-site wells were never used, apparently because of low recharge rates. The fourth well served (but was never used) as an alternate water source for the water treatment facility. A fifth on-site well provides sanitary water to the Military Van Support Facility.

IAAAP can not control the use of groundwater once it migrates off property boundaries. Prior to the early 1990s, all local residents south and southeast of the installation used private wells for drinking and irrigation (ATSDR 2003). After groundwater contamination was documented in 1992, all potentially-impacted households were afforded the opportunity to connect to the Rathbun Rural Water System at the Army's expense. Not all residents accepted the connection; 15 residents declined. By the fall of 1994, 154 residents living south and southeast of IAAAP were connected to the Rathbun Rural Water System. Rathbun water is filtered and treated to meet all federal and state drinking water standards. The closest public or municipal wells are located more than 3 miles northeast of IAAAP property and are not at risk from installation-related contamination.

Quantitative groundwater monitoring began on IAAAP and off-site locations in the 1980s. Contaminants in the groundwater included explosives (RDX, HMX, 1,3,5-TNB, 2,4,6-TNT, 1,3-DNB, 2,4-DNT, 2,6-DNT, and nitrobenzene), volatile organic compounds (VOCs) (acetone, benzene, freon, methylene chloride, 1,1-dichloroethane, 1,1-dichloroethylene, and trichloroethylene), metals (barium, cadmium, lead, iron, and manganese), semi-volatile organic compounds (SVOCs) (bis(2-ethylhexyl)phthalate), and radionuclides (radium 226/228 and gross alpha). (ATSDR 2003).

Off-site contamination was first detected above ATSDR comparison values in September 1992 during monitoring activities. Groundwater samples were collected from six residential wells located on the south/southeast border of IAAAP in the Brush Creek watershed. Two wells had explosive concentrations at levels (15.5 parts per billion [ppb] and 27.5 ppb, respectively) above the available screening value, EPA's lifetime health advisory limit (HAL), of 2.0 ppb for RDX. These wells were re-sampled on March 15, 1993; the presence of RDX at similar levels in the same wells was confirmed (ATSDR 2003).

In response to these findings, the Army conducted an extensive off-site sampling and analysis program. This program investigated all residences located in areas of suspected groundwater contamination and in the watersheds associated with surface water leaving the IAAAP. Beginning in April 1993, 54 residential wells in the IAAAP vicinity were sampled. These studies found groundwater in areas surrounding Brush Creek and a Skunk River tributary and the southern boundary of IAAAP to be contaminated with RDX. The maximum concentration found was 27.5 ppb. A supplemental groundwater investigation conducted in August 1998, indicated that RDX concentrations have decreased (maximum RDX concentration of 6.2 ppb). In general, off-site groundwater contamination appears limited to areas surrounding Brush Creek and the southern boundary of IAAAP (ATSDR 2003).

Chapter 3 Radioactivity and Radiation

This chapter contains a brief introduction and discussion of radioactivity and radiation to provide a background for discussions of the aerial survey method and its results. Naturally occurring and anthropogenic (man-made) radioisotopes, including natural background radiation levels, are discussed. The discussion includes explanations of radiation exposure and radiation dose.

3.1 Radioactivity

Elements (e.g., uranium, radium, plutonium, etc.) consist of atoms that have the same number of protons (i.e., positive particles in the nucleus of the atom). Atoms can differ in the number of neutrons (i.e., nuclear particles with no charge but about the same mass as that of a proton) within the nucleus. These different nuclear species are called isotopes (Cember 1988). Most elements have several isotopes. While differing numbers of neutrons do not affect the chemical properties of these elements, their stability can be affected. If the number of neutrons versus protons lies outside a relatively narrow range, the isotope is unstable and prone to break apart (decay). An isotope that is prone to decay is commonly referred to as a "radioisotope" because it is radioactive (emits radiation as it decays). Radiation is energy traveling in the form of waves or rays (such as photons and gamma rays) or particles (such as alpha or beta particles).

In many cases, radioisotopes undergo a series of transformations until a stable isotope is reached. This series of transformations is called a decay chain or series. The different elements that result from these transformations are called progeny or daughter products. Each isotope in these chains has its own characteristic radiation emissions, releasing radiation of a specific type and energy. Four radioactive decay chains have been identified. Three of these chains are naturally occurring and start with the following isotopes: thorium-232 (^{232}Th), uranium-238 (^{238}U), and actinouranium (uranium-235

[^{235}U]). The fourth chain is artificially produced and is referred to as the neptunium series. It begins with the isotope plutonium-241 (^{241}Pu) (Cember 1988).

The more abundant types of radiation emitted by isotopes as they decay are gamma rays, beta particles, and alpha particles. An alpha particle is composed of two protons and two neutrons. Alpha particles can be stopped (shielded) by a single sheet of paper. A beta particle is a negatively charged electron emitted from the nucleus. An electron is about 1,837 times less massive than a proton and 1,842 times less massive than a neutron. Beta particles are more penetrating than alpha particles but they are also quickly attenuated in the environment. For example, beta particles can be stopped by a thin sheet of aluminum or by a few centimeters of water. Unlike alpha and beta particles, gamma radiation has no mass and no charge. Gamma radiation can pass through paper, aluminum, or even several centimeters of lead and is thus more easily detected by remote sensors (sensors that can detect radiation at a large distance from its source) than are alpha and beta particles. This report focuses on gamma radiation.

Gamma emissions for different isotopes are known by their well-defined energy spectra and form the basis for using remote sensing devices to detect the presence of a particular isotope. Energy levels are expressed in electron volts (eV). An electron volt is the energy that an electron gains when it travels through a potential difference of one volt. A usual unit for energy is the kiloelectron Volt (keV). One keV is equal to 1,000 eV. The detection efficiency of remote detection devices depends on the energy of the gamma ray and the amount and type of matter between the decaying isotope and the detector. For example, soil and water are good shielding materials. Gamma ray emissions can be stopped by several inches of water, preventing human exposure to potentially damaging radiation (but also preventing remote detection). In contrast, air does not attenuate gamma radiation as quickly and allows detection of radioactive materials with remote sensing devices.

For some radioisotopes of concern, such as those in DU, the energies of the gamma emissions are difficult to detect. However, for many of these isotopes, the decay of one of its progeny generally provides a more easily detected gamma emission. These emissions can then be used to determine the amount of the original isotope present. DU is typically detected by the gamma emissions from the decay of protactinium-234m (^{234m}Pa), a ^{238}U progeny product with a half-life of slightly longer than 1 minute. A half-life is the amount of time needed to reduce the quantity of radioactive material present by 50%.

3.2 Radiation

Radiation is measured and reported in a number of different ways, depending on the way the measurements were made and their intended use. "Activity" is the rate of isotopic decay. Activity units are used when the concentrations of radioactive materials are needed. Because of the difference in the rates of decay of isotopes, mass measurements (grams) are not useful for quantifying these materials. Instead, the measurement unit needs to be based on the decay rate. Activity is measured as the number of disintegrations per unit time. A typical activity unit is the curie (Ci), which is equal to the activity of 1 gram of radium-226 (^{226}Ra). The international unit equivalent is the bequerel (Bq), which is defined as one disintegration per second. One curie is equal to 3.7×10^{10} Bq.

The activities of various isotopes can be measured in the laboratory from field-collected samples of soil, sediment, or water. These isotope-specific activities are then used in risk assessments to derive cancer risk estimates. They can also be used to derive estimates of the amount of radiation energy absorbed by a given mass of tissue, which determines the amount of damage done to that tissue. The amount of energy absorbed by tissue from an exposure is called a "dose." Typical dose units are the rad and the gray (Gy).

When the effects of radiation are being measured in the environment, as opposed to measurements made in the laboratory, exposure is generally measured directly. The detectors used in the aerial survey measured the amount of gamma radiation striking them each second. This value is then converted into an "exposure rate." The typical unit of exposure is the roentgen (R). A roentgen is the quantity of x- or gamma rays that produce 2.58×10^{-4} coulombs/kg of air at standard conditions of temperature and pressure. Measurements are frequently given in terms of microroentgens (μR). A microroentgen is 1/1,000,000 of a roentgen. Although not directly used in cancer risk estimates or dose calculations, exposure measurements provide a means of comparing radiation levels across large areas to determine if further investigation is required. Typically, occupational exposure level calculations use roentgens as a general exposure unit. A special unit for measuring dose in a person (called dose-equivalent) is the rem (roentgen-equivalent man). Because the rem is a fairly large dose, millirem is often used (1 millirem = 0.001 rem).

3.3 Natural and Anthropogenic Radioisotopes

3.3.1 General

Radiation comes both from natural sources (i.e., cosmic rays or terrestrial materials) and, potentially, from anthropogenic (man-made) radioactive isotopes. As noted previously, most natural elements have a number of isotopes, some of which are radioactive and subject to decay. Naturally occurring radioactive materials are found everywhere in the environment. Anthropogenic isotopes, on the other hand, are in the environment only because of their manufacture, use, and disposal by humans.

Many components contributed to forming the total gamma-ray energy spectrum measured by the sensors used in this study. These components were (1) natural terrestrial radionuclides, (2) airborne radon gas and its progeny, (3) cosmic rays, (4) anthropogenic terrestrial radionuclides, and (5) contributions from equipment used in the study.

The first three components are considered to be natural background radiation. The anthropogenic radionuclides (such as cobalt-60 [^{60}Co] and cesium-137 [^{137}Cs]) are the components of the most interest in environmental surveys. In this study, uranium is a radionuclide of interest because of testing activities involving DU. Areas with DU contributions were identified on the basis of gamma emissions from ^{234m}Pa. The fifth component category in the above list represents radioisotopes present in the measuring equipment and all electronic noise.

3.3.2 Background Radiation

Levels of background radiation in the environment are variable and depend on many factors. Local geology has a large influence on the amount of background radiation because of the varying amounts of naturally occurring radioisotopes present in different rocks and soils. Because water is a good shielding material, the amount of water in the environment can also affect the amount of background radiation emissions from the ground surface. For example, a wetland area that has a few inches of standing water will have very low levels of surface radiation emissions.

The most prominent natural isotopes usually represented in aerial gamma-ray spectra are potassium-40 (^{40}K) (0.012% of natural potassium); two progeny products in the thorium-232 (^{232}Th) chain — thallium-208 (^{208}Tl) and actinium-228 (^{228}Ac); and two progeny in the ^{238}U chain — lead-214 (^{214}Pb) and bismuth-214 (^{214}Bi). These naturally occurring isotopes typically contribute 1 to 15 μR/h (1 μR/h = 0.000001 R/h) to the background radiation field (Lindeken et al. 1972).

The contribution of radon and its progeny to the background radiation field depends on such factors as the concentration of uranium and thorium parent isotopes in the soil, the permeability of the soil, and the meteorological conditions at the time of measurement (Nazaroff 1992). Soil releases of radon produce an average air concentration of 8 becquerels per cubic meter (Bq/m^3) (216 picocuries per cubic meter, [pCi/m^3]) over the

Northern Hemisphere (NCRP 1991). Typically, the amount of airborne radiation from radon and its progeny contributes 1 to 10% of the natural background radiation level measured in aerial surveys conducted by the U.S. Department of Energy's (DOE's) Remote Sensing Laboratory.

The contribution of cosmic rays to the background radiation field varies with elevation above mean sea level and, to a lesser extent, with geomagnetic latitude and the 11-year solar sunspot cycle. Background radiation in the continental United States ranges from 3.3 μR/h at sea level to 12 μR/h at an elevation of 9,800 feet (Klement et al. 1972). Calculations of the cosmic-ray contribution used in the data analysis discussed in this report depend solely on the variation with elevation.

Background radiation exposure rates have been measured at many locations across the United States. A National Council on Radiation Protection and Measurements report (NCRP 1987) gave results from seven different studies that measured exposure rates from background radiation. The smallest study included six measurements taken near Boston; the largest study involved 9,026 measurements in 102 different towns located in 24 states (most east of the Mississippi River). The exposure rates reported in these studies ranged from 7.9 to 26 μR/h (NCRP 1987). These measurements include the exposure rate from cosmic radiation.

Chapter 4 Data Collection Method for IAAAP

4.1 Collection Area

Aerial measurement techniques were used to evaluate the radiation environment of the IAAAP. This survey included the entire site area plus some off-post areas. A total of seven flights, conducted over a 2.5-day period, were needed to complete the aerial survey at IAAAP. The survey crew arrived at Burlington, Iowa on Tuesday, October 22, 2002, and began setup the following day. However, some minor equipment problems caused a delay in the flight on Wednesday and rainstorms prevented the helicopter from flying on Thursday and Friday. Instead of the planned flight schedule of a flight on Wednesday and two flights per day on Thursday, Friday, and Saturday, the survey consisted of three flights each on Saturday and Sunday and a final seventh flight on Monday.

The rain did not affect the data from the flights. By the time flights started on Saturday morning (October 26, 2002), the water had soaked deep enough into the soil to not interfere with the gamma rays rising from the ground, and there were no areas of standing water observed during the flights. Switching to three flights per day allowed the survey to complete flying over certain regions of the Plant during the weekend and thereby minimize the disturbance of scheduled Plant operations. The final flight on Monday morning was over the far southern portion of the Plant and did not interfere with any production operations.

4.2 AMS Collection System History

The aerial measurement system (AMS) used for this project has been employed to conduct hundreds of aerial radiological surveys throughout the world. It was initially developed in 1958 and has been continuously updated since then. Surveys have been performed over most DOE and commercial nuclear reactor sites, as well as at many environmental cleanup sites.

The AMS equipment used to perform the surveys at IAAAP consisted of a radiation detector and data acquisition computer system mounted on a high-performance helicopter. A mobile data-analysis computer system supported the helicopter survey operations and allowed the spectral data to be reduced and presented as contour maps of gross counts (i.e., total number of gamma rays detected by the system) and man-made gross counts (number of gamma rays detected by the system originating from man-made sources).

4.3 Instrumentation

The IAAAP survey was conducted with an array of twelve 2- × 4- × 16-in. sodium iodide (NaI) detectors mounted beneath a twin-engine Bell 412 helicopter. A photograph showing the detectors attached under the helicopter is given in Figure 4-1. The AMS data acquisition system — Radiation and Environmental Data Acquisition and Recorder, Model V (REDAR V) — collects complete spectral information in 256 separate channels, spanning the energy range from 0 to 4,000 keV. Gamma emissions from any isotopes that are of concern at IAAAP fall within this energy range. The measured energy spectrum permits the analyst to distinguish between radiological contamination and simple changes in background radiation. The spectral information can also be used to identify specific radioactive isotopes.

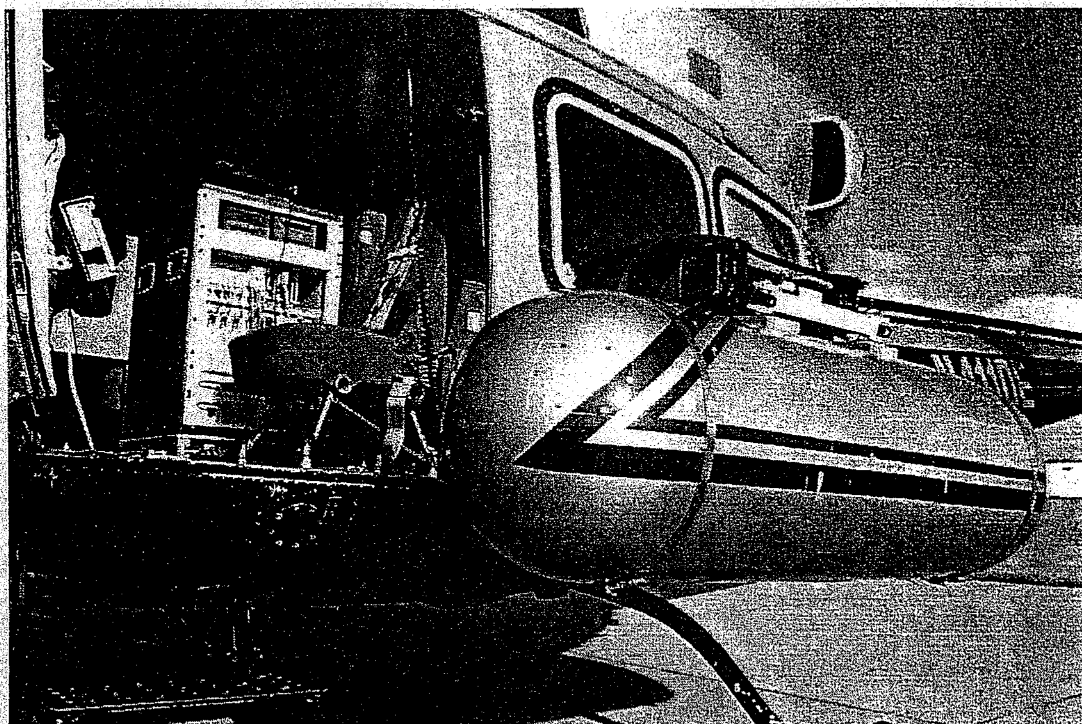


Figure 4-1 Helicopter with AMS detection system.

Table 4-1 shows examples of the strength (minimum detectable activity [MDA]) of both point and distributed surface contaminant sources (^{238}U and ^{234m}Pa) that can be detected by the AMS. In the table, the isotopes ^{238}U and ^{234m}Pa are used as examples. In an actual survey, the full spectrum of detected gamma radiation compiled by the AMS allows the identification of any gamma-emitting radioisotope present (in detectable amounts), rather than just these target contaminants. Each radioisotope decays with a characteristic set of gamma ray emissions. Each of these gamma emissions has a specific energy. By examining the energy spectrum from 38 to 3,026 keV and comparing the various energies of the detected gamma emissions, the analyst can identify the decaying radioisotope. This method allows a more accurate determination of the amounts of anthropogenic radioisotopes present compared with background levels, even if background levels change spatially over the survey area. As shown in Table 4-1, this approach has different sensitivities to different radioisotopes because of the number and energy of gamma emissions that characterize each isotope. Sensitivities for other contaminants of concern at IAAAP are given in Table 4-2 for point and distributed sources.

Table 4-1 Sensitivity of the Measurements at 60 Knots and Various Altitudes for ^{238}U and ^{234m}Pa

	12-Detector Logs	
Altitude (ft)	^{238}U	^{234m}Pa
Point Source Sensitivity (mCi)		
50	3.6	4.8
150	65	50
300	760	260
Distributed Surface Source (μCi/m²)		
50	5.5	5.5
150	15	7.5
300	60	11

[a] The ^{234m}Pa is a product of ^{238}U and can be easily associated with a ^{238}U concentration, and lower levels of activity can be detected at most altitudes.

Table 4-2 Estimated Aerial Survey Sensitivity for Other Contaminants of Concern at IAAAP

Estimated Aerial Survey Sensitivity[1]

Nuclide	Point Source MDA[2] no offset (mCi)	Point Source MDA[2] midway (mCi)	Uniform Soil[3] (pCi/g)	Surface Deposition (μCi/m²)	CERCLA Risk Range Concentrations[9] 1 x 10⁻⁶ (pCi/g)	CERCLA Risk Range Concentrations[9] 1 x 10⁻⁴ (pCi/g)
Depleted Uranium [4,8]	20 (60 kg)	45 (140 kg)	40	6.5	1.8	180
^{137}Cs	0.10	0.2	0.3	0.04	0.11	11
^{226}Ra[5]	0.70	1.8	1.4	0.30	0.026	2.6
^{239}Pu	X[7]	X[7]	3.1	0.13	14	1400

1. Twelve 16"x4"x2" NaI(Tl) detectors, altitude of 100 ft above ground level (AGL), 200 ft spacing between flight lines, velocity of 60 knots (1 knot = 1.15 mph)

2. Can be total of fragments within detector's field-of-view, whose radius is approximately the altitude above ground level
3. Other depth profiles generally have greater sensitivity, but overburden will hamper sensitivity.
4. No self-attenuation (negligible, if pieces < 0.5cm dia.)
5. Assuming concentration of surrogate (Bi-214) in secular equilibrium
6. Surrogate for Pu-239 is Am-241. Ratio of Pu:Am expected to be less than 10:1
7. Not published in public documents (classified sensitivity)
8. Concentrations of Depleted Uranium less than the specified MDA fall within the CERCLA risk range with daughter products
9. PRG for outdoor worker

All of the sensitivities cited above are for concentrations in excess of the natural background. That is, the soil activity is the sum of the concentration detected in the aerial survey, plus the average concentration in the survey area. This sum is performed for each radionuclide. The average abundance is estimated from the set of judiciously selected ground-based, corroborative measurements. Absolute measurements are possible, but require much more effort and calibration. Because absolute determination is not required, the more sophisticated procedure to obtain absolute concentrations was not included in this study.

The MDA for the contaminants of concern at IAAAP can be reduced somewhat by flying the helicopter at a lower altitude (as demonstrated for ^{241}Am in Tables 4-3 and 4-4) and a reduced velocity. However, the survey parameters selected for the IAAAP aerial survey were chosen based on meeting the objectives of the study and safety constraints.

Table 4-3 MDA Values for ^{241}Am for Three Survey Altitudes

Calculated ^{241}Am MDA for 3 Altitudes

Altitude (ft AGL)	Point Source MDA (mCi)	Planar Source MDA ($\mu Ci/m^2$)
50	0.1	0.14
100	0.3	0.23
200	2.7	0.38

Results are for a hypothetical detector array similar to that used at IAAAP

Table 4-4 Sensitivity of ^{241}Am MDA for three speeds at an elevation of 100ft

Calculated ^{241}Am MDA for 3 Speeds

Speed (knots)	Point Source MDA (mCi)
30	0.2
60	0.3
120	- 0.4

Hypothetical detector array

Helicopter flight positions during the surveys were continuously determined with a radar altimeter and a real-time differential global positioning system (RDGPS). The RDGPS provides latitude and longitude position with an accuracy of better than ±5 m (16 ft). With this RDGPS, GPS data from a network of precisely measured locations surrounding the United States is transmitted to a control center, where range, timing, and ephemeris errors from the 24 GPS satellites are evaluated. Corrections for each satellite are then up-linked to a geo-stationary satellite, broadcast back to earth, and utilized by the helicopter RDGPS. Without these corrections, GPS accuracy would have been ±20 to 30 m (66 to 98 ft). The radar altimeter determined the helicopter's altitude by measuring the round-trip propagation time of a signal reflected off the ground. For altitudes up to 300 m (984 ft), the accuracy of this system is ±0.6 m, or ±2%, whichever is greater.

In aerial surveys (Figure 4-2), an aircraft's altitude, flight line spacing, and speed are chosen to optimize the detector sensitivity to radioisotopes and spatial resolution while maintaining a safe and efficient flight configuration. For the IAAAP survey, the position information was directed to an aircraft steering indicator used to guide the aircraft along predetermined, parallel flight lines. The position information from the DGPS system and the radar altimeter data were simultaneously recorded, along with the spectral information from the NaI(T1) detectors, at 1-second intervals for post-flight analysis.

A computer-based system, the Radiation and Environmental Data Analyzer and Computer (REDAC) system, was used to evaluate the acquired data immediately following each survey flight. The REDAC system consists primarily of two computers, a printer, software, and a large-bed plotter.

4.4 Collection Methods

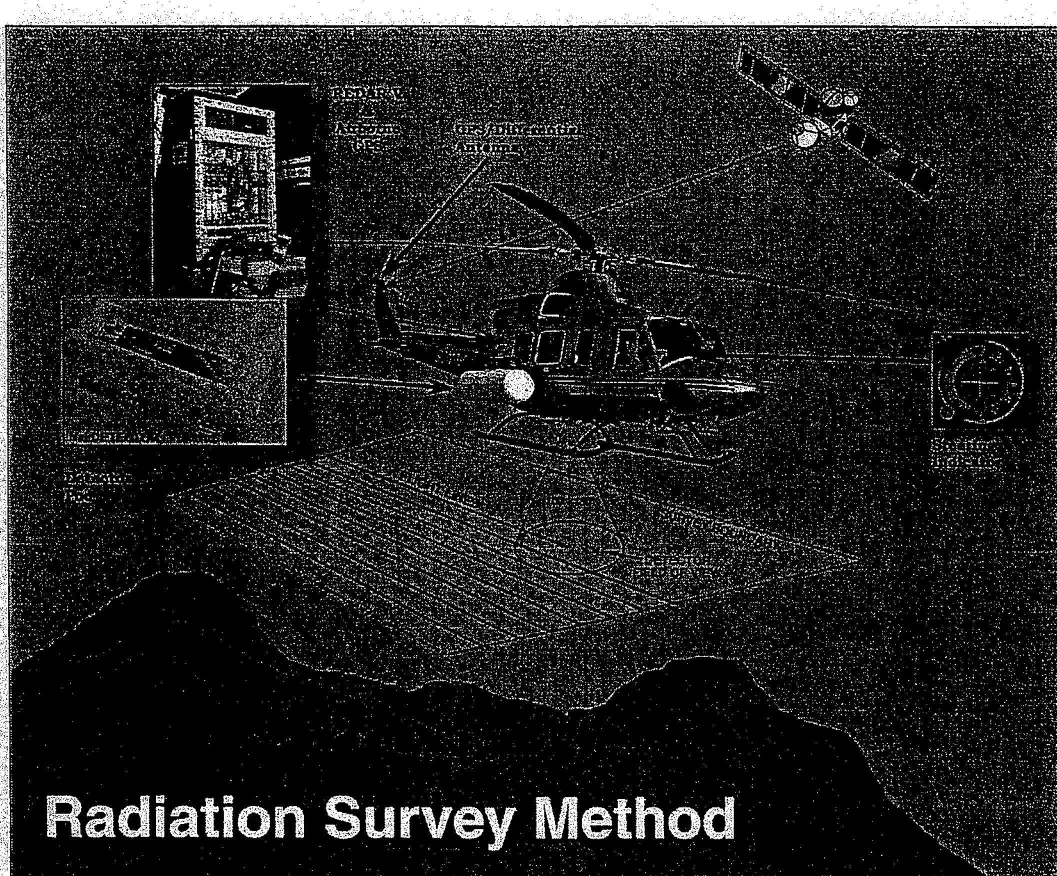
4.4.1 Aerial Data Collection

Data were collected from a Bell 412 helicopter. The helicopter was flown at a constant speed of 60 knots (69 mph) and an altitude of 100 feet over the survey area in a series of parallel flight lines spaced 200 feet apart. This procedure continued until all of the desired area was surveyed.

The data set, collected at the rate of one measurement per second during the flight, consisted of position and altitude data, atmospheric information, and gamma-ray energy spectra. The first portion of the flight was a reconnaissance flight conducted above 500 ft to verify and update the existing flight-hazard maps. The hazards maps were updated with the locations of towers, power lines, or other high structures that would present a hazard to a helicopter flying at 100 ft above ground level (AGL).

The direction of the flight lines was chosen to minimize the amount of time consumed turning around, and thus minimize the time necessary to cover the area. Each flight included a pass over the test line, passes over the lines in the survey area designated for that flight, and then a repeat of the test line before landing. These procedures are described in detail below.

Flights over the test line were used to determine the contribution of cosmic and atmospheric radiation to the measurements. The test line was located just east of the survey area and was a 6,000-ft long path along Line 22. The line was predominantly over agricultural fields, with very few homes nearby.



4.4.2 Calibration and Data Quality

Fluctuations in atmospheric radon and cosmic radiation were measured during the survey. These data were then analyzed to determine the gamma ray contribution from atmospheric and cosmic sources. In the subsequent calculations, appropriate algorithms were applied to the aerial survey data to remove the count rates from radon, equipment, and cosmic radiation.

For the surveyed area, a perimeter was flown over identifiable ground objects, such as roads and railway lines. Data from these perimeter flights were used as a quality check for the GPS data by visually matching the flight path flown with specific locations on a detailed map of the site.

An altitude profile (also referred to as an altitude spiral) was flown early in the survey period. The altitude profile consisted of several traversals of a specific path (the test line for this survey) conducted at five or six different altitudes. For the IAAAP survey, a maximum altitude of 500 ft was used. The altitude spiral was performed in order to determine an appropriate attenuation coefficient for gamma rays with increasing altitude and an initial background concentration. These values were then used to adjust the aerial measurements for minor fluctuations in altitude during subsequent flights.

4.4.3 Ground-Truth Measurements

As a quality control check on the aerial data, measurements were also made on the ground (ground-truth measurements) at selected locations and compared with aerial data from the same locations. The locations and results of these ground-truth measurements are presented in Section 4.8. The ground-truth measurements were made with a Reuter-Stokes ion chamber instrument (Reuter-Stokes Model RSS-112, GE Reuter-Stokes, Twinsburg, Ohio). The system measured the total exposure rate at a height of 1 m. This measurement provided an independent means of confirming the conversion from airborne counts to exposure rates.

Ground measurement locations had to be selected so that no interfering structures, such as large expanses of concrete, asphalt, or buildings, would be located nearby. This restriction usually dictated that readings had to be made in open, grassy areas. The exposure rate was an average over approximately 15 minutes.

4.5 System Sensitivity

The AMS can detect small changes in radiation over the detector footprint. The footprint of the detector extends out to a boundary defined as the location at which the count rate falls to one-half its original value. For aerial flights, the radius of the footprint is approximately equal to the altitude of the helicopter. Landscape features such as lakes and creeks are easily detectable because of the shielding effects of the water (areas of low gamma counts). In addition, heavy vegetative cover also can reduce the amount of radiation reaching the detectors. This effect is generally caused by the moisture present in the leaves and other plant structures. Bare or recently disturbed soil has the highest gamma emissions (in areas without anthropogenic contributions to the gamma emissions) because the natural gamma emissions are not shielded from the detector. Concrete structures and buildings can also show up in the survey results because of gamma emissions from naturally occurring radioisotopes present in construction materials and the lack of any vegetation to shield the emissions from the detectors. This correlation of survey results with identifiable surface features provides an additional quality check on the collected data.

4.6 Data Analysis Algorithms

4.6.1 Gross-Count Method

To obtain a gross-count (GC) contour, the count data collected by the AMS equipment were first integrated between 38 and 3,026 keV:

$$G_c = \sum_{E=38}^{3026} c(E) \ , \qquad (1)$$

where

G_c = gross count rate (counts per second [cps]),
E = gamma ray energy (keV), and
$c(E)$ = count rate in the energy spectrum at the energy E (cps).

The system records gamma rays with energies up to 4,000 keV; however, there are very few gamma rays that have energies greater than 3,000 keV.

Because GC contours are meant only to depict terrestrial radiation levels, counts from cosmic radiation and airborne radon must be subtracted. Furthermore, the terrestrial GC rate was converted to an exposure rate at 1-m (3.3-ft) height by applying a conversion factor. The calculations for the exposure rate, E_G, are summarized below. All counts were normalized using detector live time.[i]

$$E_G = \frac{G_C - B}{S_f} e^{\mu(H-100)} , \qquad (2)$$

where

E_G = exposure rate (μR/h),

B = background count rate from cosmic radiation, atmospheric radon, and aircraft materials (cps) (this parameter differs from total background radiation in that the latter includes all sources with the exception of anthropogenic contamination),

H = helicopter's altitude (ft),

S_f = conversion factor

μ = an attenuation coefficient (1/ft).

The background count rate from cosmic radiation, atmospheric radon, and helicopter materials was determined by flying the aircraft over a body of water, which shielded the AMS instruments from terrestrial sources of radiation. Over water, the only counts measured were those from cosmic radiation, radon, and aircraft materials. The contours generated from these data reflect the exposure rate at a height of 1 m from terrestrial sources (the background exposure rate has been subtracted). A typical, and highly variable, contribution from radon (approximately 0.2 μR/h) was ignored.

The factor S_f in Equation 2 converts count rate (counts per second) to an exposure rate (μR/h) and was determined from data obtained over a calibration line at Lake Mohave in Nevada. The factor relating count rate to exposure is 1,879 cps/μRh. The exponential term in Equation 2 corrects for changes in the attenuation of the gamma radiation in air

i "Live time" is the amount of time over which the detector integrates readings.

because of slight variations in the aircraft's altitude. The attenuation coefficient, μ, was obtained from experimentally measured data collected from the altitude spiral survey.

The conversion from gross counts to an exposure rate is based on the assumption that the source is spread uniformly over the width of the detector footprint, or field of view, of about 100 feet. Because of this assumption, the exposure rate will be underestimated for sources that are less than 100 feet in diameter.

Gross-count data include contributions from natural sources of radiation. Consequently, these data reflect variations in terrestrial background radiation levels. Contours resulting from these variations in natural radiation often match specific surface features, such as tree lines, boundaries of cultivated land, and bodies of water, because of the different attenuation characteristics of the different materials. Exposure rate contours offer a sensitive means of identifying anomalous, potentially anthropogenic changes in the radiation environment, in addition to detailing variations in the natural background radiation emissions.

4.6.2 Man-Made Gross-Count Method

The man-made (anthropogenic) gross-count (MMGC) method is used to differentiate between anthropogenic radiation and naturally occurring radiation in a survey. The MMGC method, also referred to here as the "MMGC filter," relies on the fact that most gamma ray emissions from long-lived, anthropogenic sources of radioactivity occur in the energy region below about 1,400 keV. In areas in which only natural sources of gamma radiation are present, the ratio of the counts appearing below 1,400 keV to those appearing above 1,400 keV remains relatively constant. This relationship is true even if natural background radiation levels vary by a factor of 10 across the survey area. If this ratio changes spatially, it is most likely because of a contribution from anthropogenic gamma radiation.

The MMGC algorithm provides a means of identifying regions in the survey area where the shape of the energy spectrum deviates significantly from the shape of the background, or reference, spectrum. The MMGC algorithm is very insensitive to small changes in the abundance of anthropogenic isotopes, while being very sensitive to large changes in the abundance of natural isotopes.

Figure 4-3 shows two typical NaI gamma ray spectra. Superimposed on a background spectrum is a spectrum obtained with ^{60}Co present. Counts from an anthropogenic radioisotope such as ^{60}Co fall almost entirely in the low-energy region below 1,400 keV. This condition is true for most anthropogenic radioisotopes of concern. The distribution of energy in the spectrum causes the ratio of counts in the low-energy range to counts in the high-energy range to change.

The normal ratio of counts in the low-energy region to counts in the high-energy region for a survey area is calculated from data obtained in an area that contains only natural sources of radioactivity. These counts are integrated over each energy region. To match the energy limits of the discrete channels of the acquired spectra, the low-energy region extends from 38 to 1,394 keV. The high-energy limits are then 1,394 to 3,026 keV. This ratio can be computed with Equation 3:

$$K_{MM} = \frac{\sum_{E=38}^{1394} c_{ref}(E) - B_{MML}}{\sum_{E=1394}^{3026} c_{ref}(E) - B_{MMH}} , \qquad (3)$$

where

K_{MM} = ratio of low-energy counts to high-energy counts in the reference region of the survey,

B_{MML} = average background counts in the MMGC low-energy window (cps), and

B_{MMH} = average background counts in the MMGC high-energy window (cps).

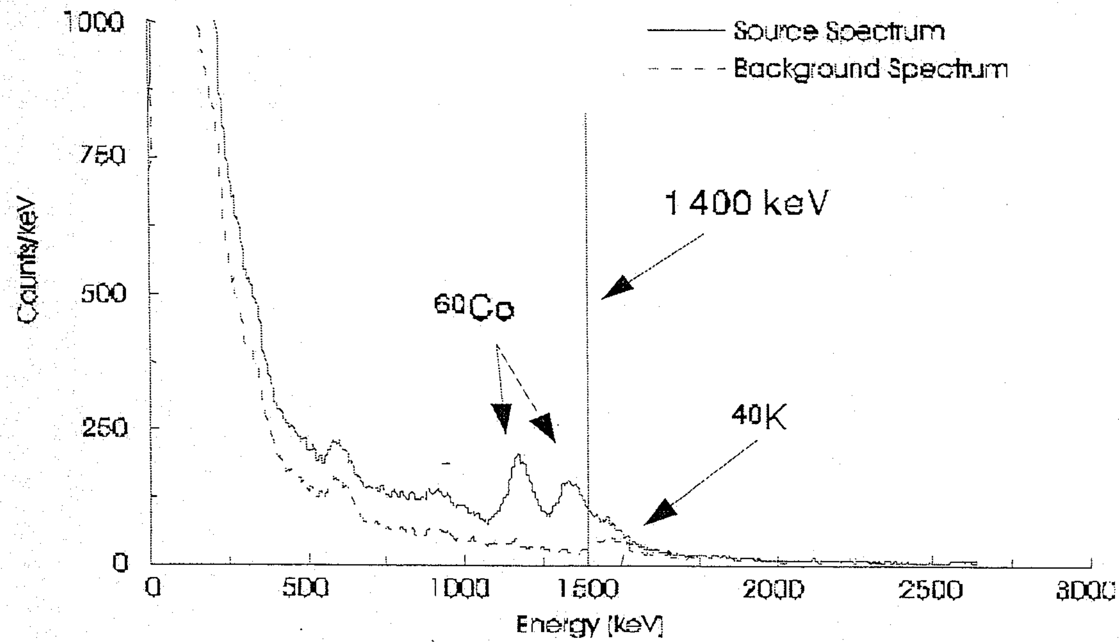


Figure 4-3 NaI gamma ray spectrum illustrating MMGC energy regions.

The background count rates are derived from data in the reference region of the survey. These two background count rates remove the effect of nonterrestrial background from the MMGC extraction in a manner similar to the background removal in the GC algorithm. The subscript "*ref*" indicates that the counts in each channel, *c(E)*, are obtained from a reference area of natural background radiation. This ratio is applied to each second of data from the survey area:

$$C_{MM} = \left[\sum_{E=38}^{1394} c(E) - B_{MML} \right] - K_{MM} \left[\sum_{E=1394}^{3026} c(E)\, B_{MMH} \right], \qquad (4)$$

where:

C_{MM} = anthropogenic (man-made) count rate (cps).

The MMGC algorithm allows the data to be analyzed such that variations in the count rate due to changes in natural background levels are filtered out. In regions with only natural background radiation, the MMGC algorithm will yield count rates that fluctuate statistically around zero. Variations in count rate due to anthropogenic or industrially enhanced radioisotopes then appear as isolated contours with higher concentrates.

The increase in sensitivity obtained with the MMGC analysis over that of the gross-count method is significant. However, the MMGC filter is also sensitive to changes in the relative composition of natural background radiation. For example, areas where uranium (a naturally occurring radioisotope) is naturally high relative to the other natural radioisotopes can appear as anomalies when this algorithm is used.

4.6.3 Isotope Extraction Algorithms

The algorithms employed in the search for particular isotopes are very similar to the MMGC algorithm. The major difference is that instead of using the full gamma-ray energy spectrum, only a few small portions of it are used. One such calculational procedure is the "2-window algorithm."

The 2-window algorithm is the simplest of several window algorithms in use. It employs a narrow window centered on the energy of the specific photopeak of the isotope of concern. The algorithm assumes that the background counts in the photopeak window are proportional to the counts recorded in a background window located at higher energies. The background window may be adjacent to the photopeak window or may be separated from it in energy. Note that the form of the equation for $C_{2\text{-}Window}$ given below is identical in form to the equation for MMGC previously defined:

$$C_{2\text{-}Window} = \left[\sum_{E=E_1}^{E_2} c(E) - B_{2L} \right] - K_2 \left[\sum_{E=E_3}^{E_4} c(E) - B_{2H} \right], \qquad (5)$$

with

$$K_2 = \frac{\sum_{E=E_1}^{E_2} c_{ref}(E) - B_{2L}}{\sum_{E=E_3}^{E_4} c_{ref}(E) - B_{2H}}, \qquad (6)$$

where

$C2_{\text{-}Window}$ = count rate from the 2-window algorithm (cps),

$c(E)$ = count rate in the gamma-ray energy spectrum at the energy E (cps),

E_n = limiting energies of the windows ($E_1 < E_2 \le E_3 < E_4$) (keV),

K_2 = ratio of the counts in the photopeak window to the counts in the background window in the reference region of the survey area,

$c_{ref}(E)$ = count rate in the reference gamma-ray energy spectrum at the energy E (cps),

B_{2L} = average background counts in the 2-window low-energy window (cps), and

B_{2H} = average background counts in the 2 window high energy window (cps).

The proportionality factor, K_2, is determined in a region of the survey that does not contain any of the specific isotope of concern, so that the photopeak window contains only background counts and, therefore, can be simply related to the number of counts in the background window. If the principal source of background gamma rays in the photopeak window is from scattered gamma rays from photopeaks at higher energies, this is a good assumption. If there are other isotopes with photopeaks in or near the photopeak and background windows, this algorithm fails. The presence of depleted uranium is typically detected by the high-energy gamma rays emitted by its progeny ^{234m}Pa. At IAAAP, the energy of these gamma rays is relatively isolated from the natural background gamma ray energies and the 2-window algorithm works well.

4.6.4 Gamma Spectral Analysis

The MMGC algorithm is very general and sensitive to any change in the low-energy portion of the spectrum. It does not exactly identify the causes of the change — whether (1) a true anthropogenic isotope is present in this region, (2) the increased low-energy gamma rays are caused by naturally occurring isotopes whose gamma rays underwent more inelastic scatterings before reaching the detectors (for example, a change from a grassy meadow to a dense wooded area), or (3) the isotopic composition of the spectrum in this region of the survey is significantly different from where K_{MM} was determined (for example, granite versus limestone). Once a region appears in the anthropogenic contours, the energy spectrum is searched for individual isotopes. An analysis of the gamma-ray spectrum is used to identify the isotopes that are present in the spectrum and caused the MMGC deviation.

Generally, the large background field (from the naturally occurring isotopes) is not of interest — only the portion of the spectrum attributable to the anthropogenic isotopes. Unfortunately, the number of counts at any given energy in a single 1-second measurement is so small as to make the identification of a particular isotope very difficult. To increase the number of counts in the spectrum being analyzed (and thus produce better statistics), the spectra from neighboring measurements are combined to produce a single spectrum showing the radiation measured over some larger area.

To determine net spectra at an identified anomaly, each area of interest is divided into "peak" and "background" regions. The contour levels used to define these regions are usually MMGC levels. The peak and background boundaries may be defined by other means, for example, GC contour levels. The peak region of the spectrum consists of the spectra contained in the area bounded by the chosen contour level. The background region consists of the spectra contained outside the chosen contour level. This partitioning generally guarantees that the background spectrum is representative of the geology near the anomaly, but there will be some contribution of anthropogenic radioactivity in the background region.

This technique produces a net spectrum that has very little contribution from the naturally occurring radionuclides in the region and makes the identification of the remaining isotopes fairly easy. The technique has one major drawback in that it does not necessarily produce a true indication of the strength of the isotopes seen in the net spectrum. That is, comparing the intensity of an isotope in one net spectrum with the intensity of that same isotope in another spectrum may not be meaningful.

Numerous techniques can be used to scale the background spectra when creating the net gamma-ray spectra. The technique used on the IAAAP data was to compute the ratio of the live times of the peak and background regions and use the results to normalize the data. The technique used on these data creates a net spectrum by subtracting the background spectrum, normalized by the ratio of the peak live time to the background live time, from the peak spectrum:

$$c_{Net}(E)=c_{Peak}(E)-\frac{T_{Peak}}{T_{Bkg}}c_{Bkg}(E) \ , \tag{7}$$

where:

$c_{Net}(E)$ = counts in the net energy spectrum at the energy E (cps),

$c_{Peak}(E)$ = counts in the peak energy spectrum at the energy E (cps),

T_{Peak} = total spectrum live time comprised of all peak-region spectra (s),

T_{Bkg} = total spectrum live time from all background-region spectra (s), and

$c_{Bkg}(E)$ = counts in the background energy spectrum at the energy E (cps).

This method of normalization is relatively straightforward to implement. If there is an excess of naturally occurring radioisotopes, the net spectrum will preserve the high-energy photopeaks of these isotopes.

4.7 Detection Sensitivity

On November 12, 2002, a test flight was conducted with the helicopter system in a desert area near the Remote Sensing Laboratory in Nevada over a set of DU sources. Eleven 9-kg sheets (each measuring 7" x 9 ½ " x ½ ") of DU were placed under the flight path of the helicopter. The helicopter flew a small survey pattern over the sources at four altitudes: 15 m, 30 m, 45 m, and 90 m (50, 100, 150, and 300 ft). The flight line spacing for these surveys was set equal to the altitude of the aircraft. At the lower altitudes, seven 2-km length lines were flown, while only five lines were flown at the highest altitude. The helicopter speed was 60 knots, the same velocity as that used during the IAAAP survey.

The data were analyzed in the same manner as the survey data. The two-window algorithm discussed above was used to extract the DU count rate. Because there are two principal gamma-ray energy ranges that can be used to identify DU, this study investigated them both. The low-energy region is populated by the decay of ^{234}Th (the first daughter of ^{238}U) and contains gamma rays with energies of 63.3 keV (about 3.8% of all decays) and 92.5 keV (about 5.4% of all decays). The high-energy region is populated by the decay of ^{234m}Pa (the first daughter of ^{234}Th) and contains gamma rays with energies of 767 keV (about 0.21% of all decays) and 1,001 keV (about 0.59% of all decays).

The gamma rays are attenuated in differing amounts depending on their energy. The low-energy gamma rays are easily attenuated by air, but a larger problem is the self-shielding of the DU plates. For the 1.3-cm (1/2-inch) thick DU plates used in this study, nearly all of the low-energy gamma rays that leave the plate originated in the top 0.08 cm (0.03 inch). Thus, only the top 6% of the plate contributes low-energy gamma rays for this study. The atmospheric attenuation (over a 30-m distance) will reduce the number of low-energy gamma rays to about 50% of the original value.

The high-energy gamma rays are not much affected while passing through the air, and only moderately affected by the self-shielding of the plates. At 1,001 keV, approximately 45% of all gamma rays leave the plate unaffected. The atmospheric attenuation (again over a 30-m distance) will reduce the number of high-energy gamma rays to about 80% of the original value. The value calculated in Nevada would be nearly the same as a value calculated at the IAAAP because atmospheric effects are negligible.

Thus, for this study, the eleven 9-kg plates of DU represent (at 0.335 mCi/kg) a total of 2 mCi of the 92.5-keV gamma rays and 15 mCi of the 1001-keV gamma rays. The sources were visible in the study data only on the lower two altitudes. At a 15-m (50-ft) altitude, the low-energy gamma rays from DU are detected by the two-window algorithm above the four standard deviation (4σ) level. The high-energy gamma rays from DU are detected above the 3σ level. At a 30-m (100-ft) altitude, the low-energy gamma rays are not observed. The high-energy gamma rays are detected at about the 2σ level. That is, in about 95 out of 100 measurements, the high-energy gamma rays would be detected.

If the MDA for detecting DU during the IAAAP survey (conducted at a 100-ft altitude) is defined as the activity needed to reach a confidence level of 3σ (99.7% of measurements would detect the high-energy gamma rays) the high-energy gamma rays can be used in the analysis, and the MDA will be about 22 mCi, which is comparable to the calculated value of 20 mCi cited in Table 4-2.

4.8 Ground Measurements

A series of ground-based measurements was conducted on the afternoon of October 28, 2002. These measurements were conducted with a pressurized ionization chamber (PIC) and a high-purity germanium detector. The ground-based measurements were intended to provide an independent confirmation of the aerial data. Measurements were conducted at a total of five locations chosen from areas in which the aerial survey data indicated the terrestrial radiation was relatively constant (see Figure 5-2).

The PIC measurements consisted of 5-minute averages of the exposure rate at each location. If the first two 5-minute averages did not agree within the uncertainty, a third 5-minute average was taken at that location. The data are shown in Table 4-5.

Table 4-5 Exposure Rates from Five-Minute PIC Measurements

Nearby Facility	Latitude (deg) N	Longitude (deg) W	PIC Measurement (μR/h)					
			#1	Uncert.	#2	Uncert.	#3	Uncert.
Yard F	40.81469	91.28351	9.4	0.8	9.4	0.3		
Line 1	40.82084	91.22405	8.8	1.4	9.5	0.4	9.5	0.5
Line 7	40.797789	91.24784	8.9	0.4	9.4	0.4	9.5	0.5
Yard C	40.79346	91.21350	7.6	1.7	8.1	0.4	8.1	0.4
Yard E	40.78274	91.22891	8.6	1.7	9.5	0.4	9.6	0.5

The germanium detector measurements consisted of gamma ray spectra collected for a period of 15-minutes at each location. The spectra were analyzed to identify the gamma-ray emitting isotopes present in the surrounding soil. Isotopes observed in the spectra were the naturally-occurring radioactive isotopes of ^{40}K, the ^{238}U decay chain (^{214}Bi, ^{214}Pb, and ^{226}Ra), and the ^{232}Th decay chain(^{208}Tl, ^{212}Bi, ^{212}Pb, ^{224}Ra, and ^{228}Ac). In addition, ^{137}Cs, from world-wide fallout could also be seen at several of the sites.

The table below converts measured DU count rates into soil concentrations.

Table 4-6 Estimated Concentrations of DU in the Soil on the Basis of Measured Gamma Emissions from ^{234m}Pa for Two Soil Concentration Profiles[a]

	Source Distribution of DU based on ^{234m}Pa Counts			
^{234m}Pa Net Count Rate (cps)	**Point Source (mCi)**	**Uniform Depth (pCi/g)**	**Exponential Depth[b] (pCi/g)**	**Surface (μCi/m²)**
45	40	36	31	5.8
80	71	64	56	10.4
140	125	112	98	18.2
250	222	200	175	32.5
450	400	360	315	58.5
800	712	640	560	104.0
1400	1246	1120	980	182.0
2500	2225	2000	1750	325.0

a Also shown are estimated point source and surface source strength on the basis of measured gamma emissions.

b Where the distribution is of the form $A = A_0 e^{(-z/z_0)}$ with $z_0 = 3$ cm, and where the measured activity is averaged over the top 2.5 cm.

Chapter 5 Results of the Aerial Survey

Results of the AMS aerial survey performed for the IAAAP are presented in two different forms: gross counts (GC), and man-made gross counts (MMGC). Gross counts represent the total quantity of radiation present from terrestrial sources, both man-made and naturally occurring background. The gross-count data are presented in terms of counts per second (cps). Higher counts represent greater amounts of radioactivity. Filtered data for ^{226}Ra, ^{241}Am (^{239}Pu surrogate), and ^{137}Cs are not presented because the aerial survey did not find any significant evidence of these isotopes in the gamma energy spectra. Because DU was the prevalent isotope found during the aerial survey, its distribution and concentration are represented by the MMGC results.

MMGC data are also presented in the form of counts per second and represent areas at the IAAAP where the ratio of gamma radiation from all man-made radioisotopes to the remaining gamma spectrum is above normal (at the 3σ level), as determined by the analyses methods present in Section 4. Man-made gross counts thus represent data in which variations in the count rate produced by changes in the natural background levels have been filtered out. MMGC data can also highlight locations that have large variations in background gamma emissions because of different geologic materials or rapidly changing readings caused by elevation variations in the detection system during measurement. Such changes can occur when the elevation of the terrain changes more rapidly than the helicopter can follow. The method for altitude adjustment discussed in Section 4 can accommodate small changes in the altitude of the helicopter, but rapid elevation changes over an area, especially those areas in which background emissions are rapidly changing, can produce anomalies in the processed data.

5.1 Gross Counts

Figure 5-1 shows the flight lines taken by the helicopter during the AMS aerial survey. Off-post areas surveyed are clearly seen surrounding the site. Figure 5-2 shows the gross-counts results for the AMS aerial survey for the entire IAAAP facility and off-post areas. The number of gamma ray counts per second ranged from approximately 1,700 to 68,000 cps for a total of 50,333 data points in the survey. The mean gross-count rate was about 9,200 cps, and the statistical standard deviation of the counts was approximately 1,500 cps. Large portions of the facility have gross counts in the range of 9,000 to 12,000 cps. Figure 5-3 shows the cumulative distribution of gross counts obtained during the aerial survey. Nearly 100% (99.79%) of the data measurement points had count rates that were less than 12,000 cps; 50% of the measurement points had gross-count rates of less than about 9,500 cps.

Low count rates (3,000 to 5,000 cps) coincide with areas of surface water (e.g., the Skunk River along the southern boundary of the facility, Brush Creek, Spring Creek, Long Creek, and Mathes Lake. The highest count rates (>26,000 cps) occurred in the east central portion of the facility (Yard E).

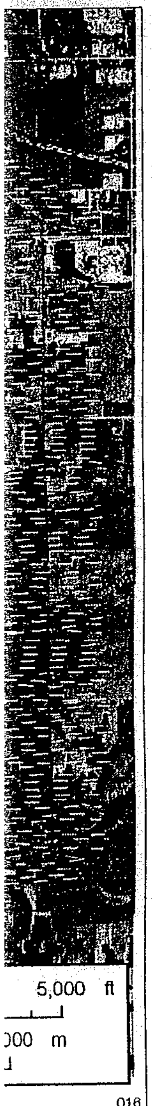


Figure 5-1 Flight lines taken by the helicopter taken during the AMS aerial survey.

2003

Figure 5-2 Gross-count results for the AMS aerial survey for the entire IAAAP facility.

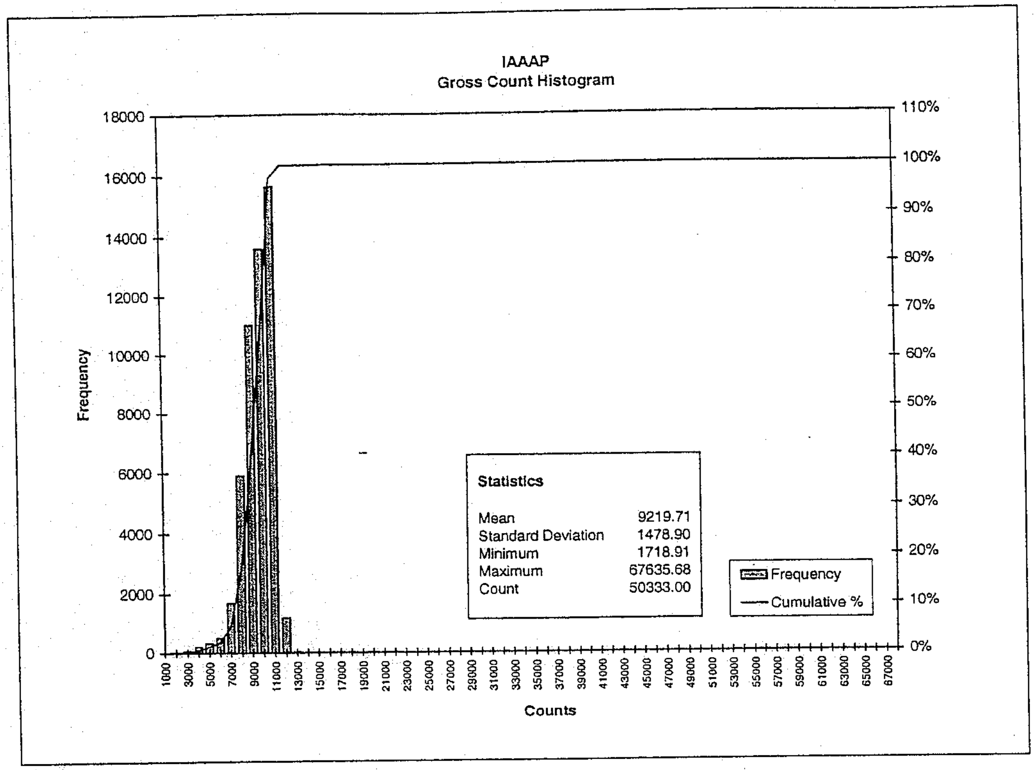


Figure 5-3 Cumulative distribution of gross-counts obtained during the aerial survey

5.2 Man-Made Gross Counts

Figure 5-4 shows the man-made gross count results for the IAAAP survey. Figure 5-5 shows the MMGC cumulative distribution. The minimum MMGC was about -1,778 cps, the maximum MMGC was about 32,260, and the mean value was about 26 cps. A total of 50,333 data points were recorded. The standard deviation for the MMGC was about 555 cps. A non-zero mean count (26 cps) indicates anomalies are present in the data.

Three regions with anomalously high results are apparent in Figure 5-4. These regions correspond with Firing Site 12, the coal pile, and Yard E. Close-ups of these regions are given in Figures 5-6 through 5-10. Additional close-ups that show the actual MMGC counts and the flight lines across these areas are given in Figures 5-11 through 5-13. For these figures, the highest MMGC counts often coincide with buildings in Yard E.

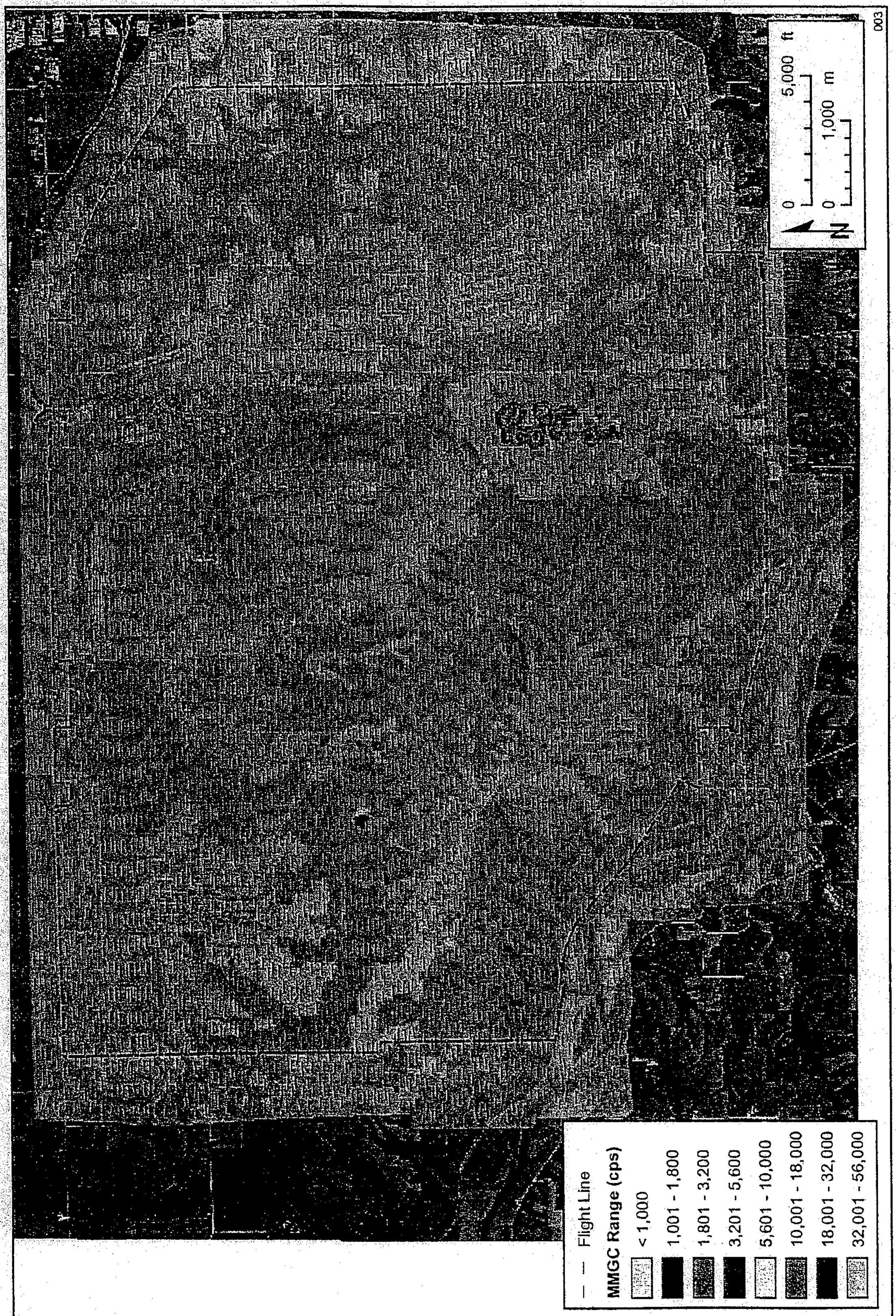


Figure 5-4 Man-made gross count results for the IAAAP survey

Most of the high count rates in Yard E coincide with material stored inside the buildings. High count rates that are offset from the buildings can be caused by the sampling distance between sampling points (at a flight speed of 60 knots, the distance between measurements taken one second apart is about 100 ft), or by source material outside of the buildings. The actual source of these high counts can not be determined from the aerial survey data.

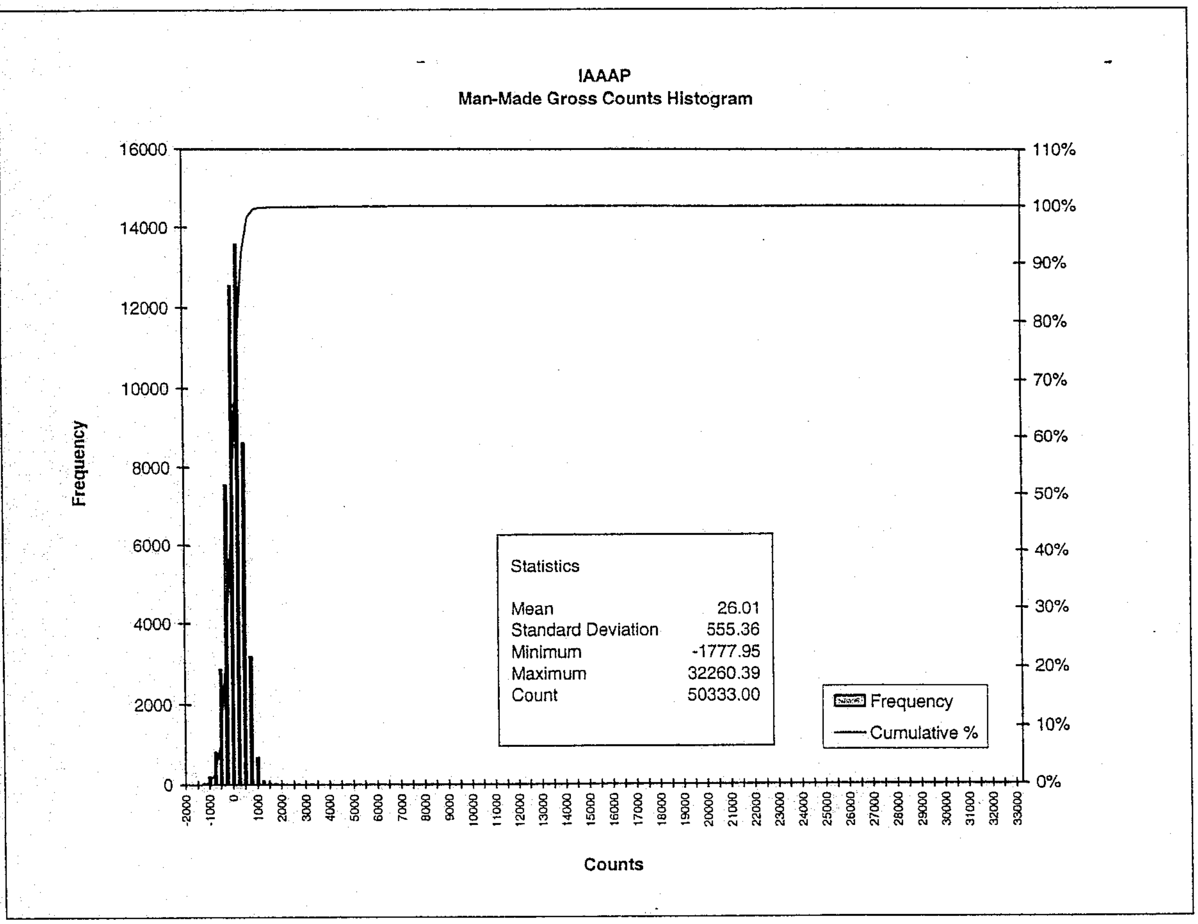


Figure 5-5 Cumulative distribution of man-made gross-counts obtained during the aerial survey.

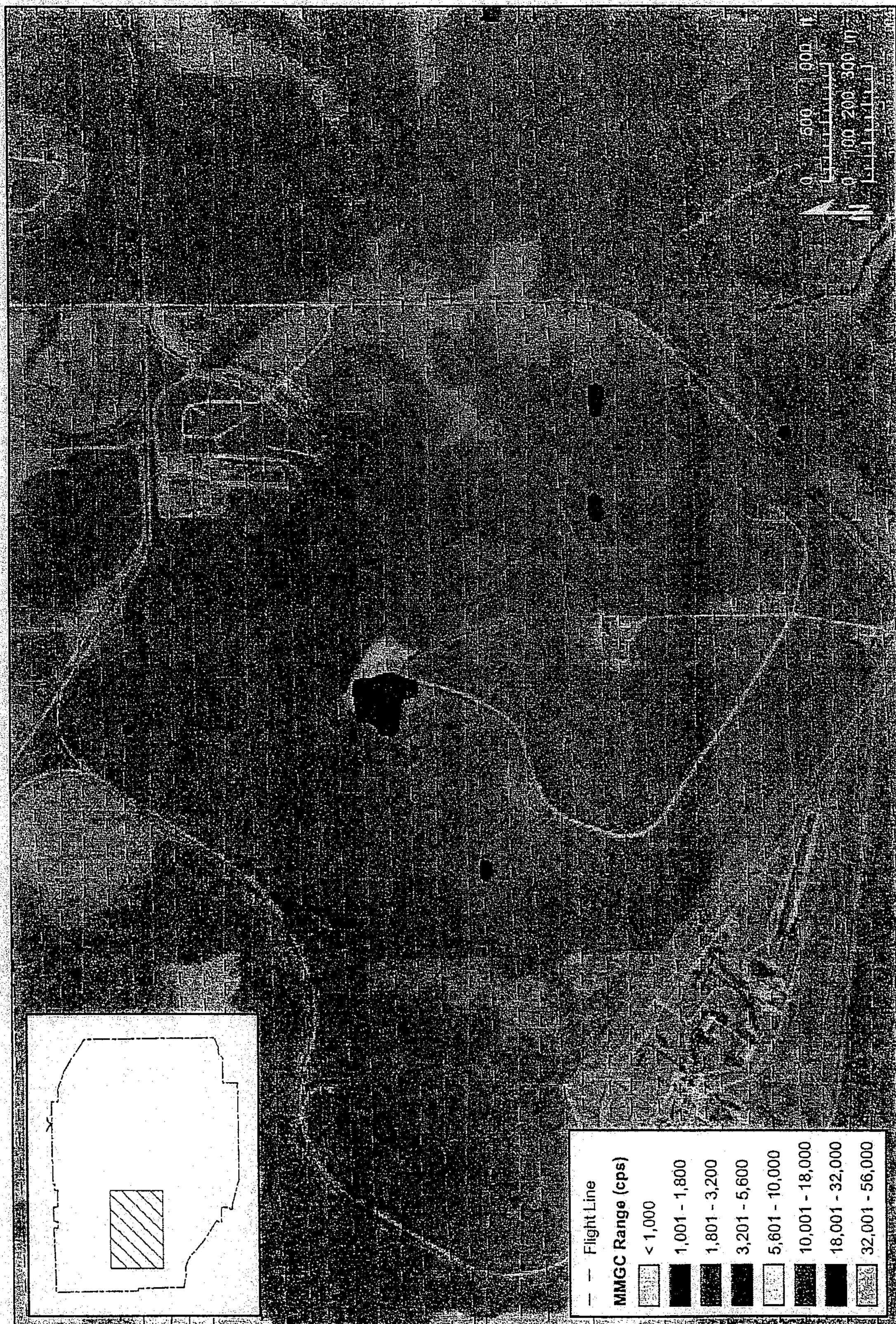


Figure 5-6 Firing Site 12 MMGC

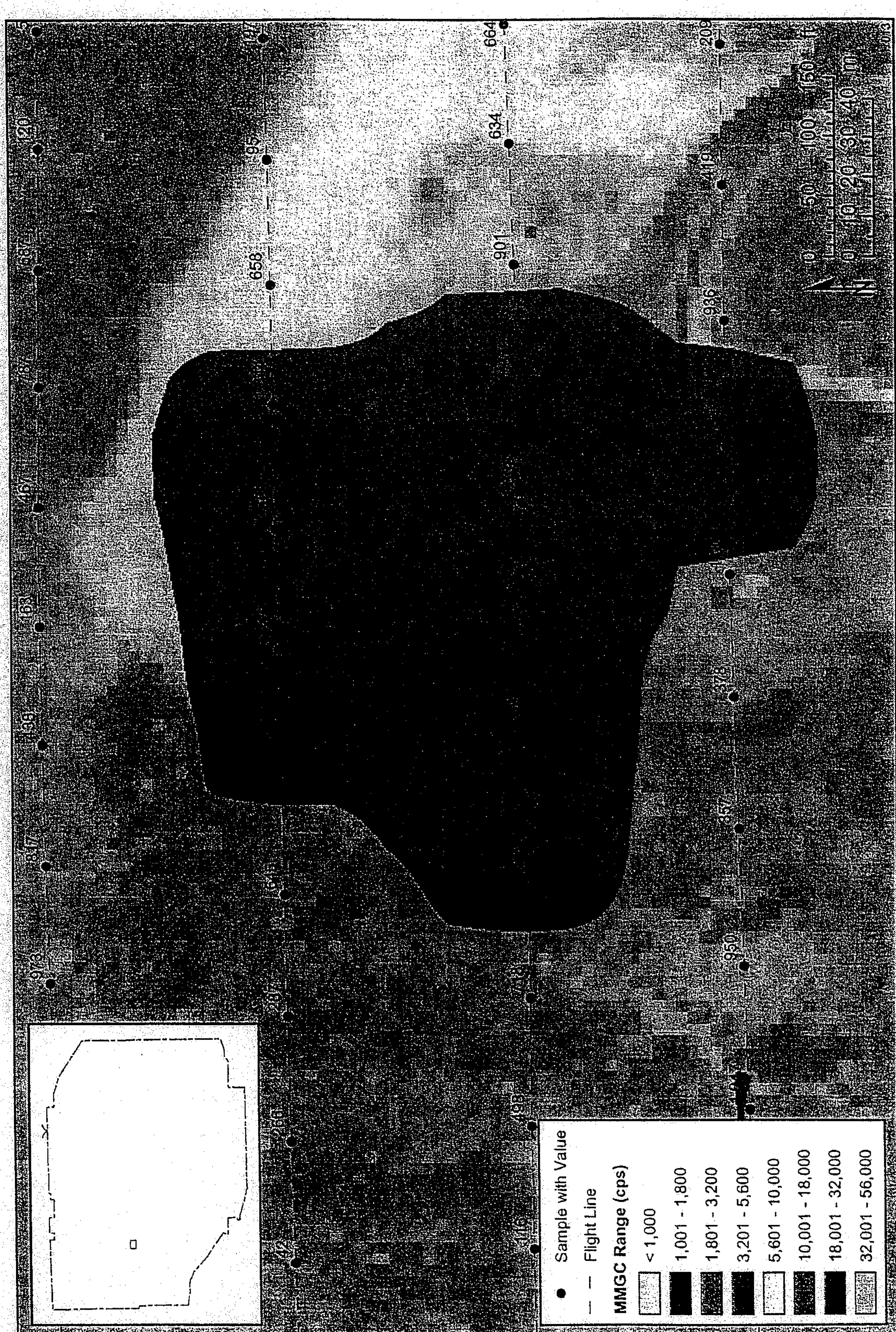


Figure 5-7 Closeup of Firing Site 12.

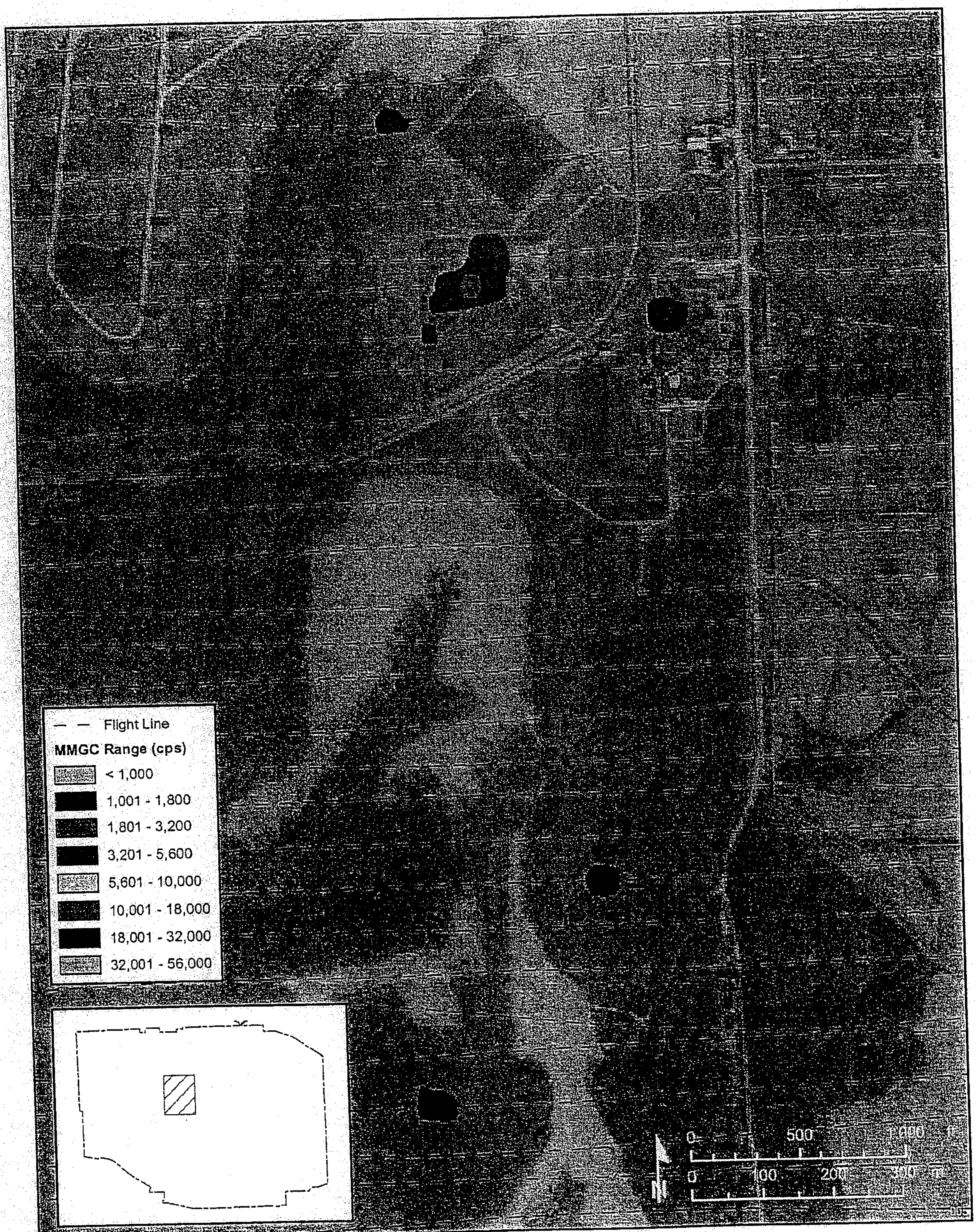


Figure 5-8 Coal pile MMGC

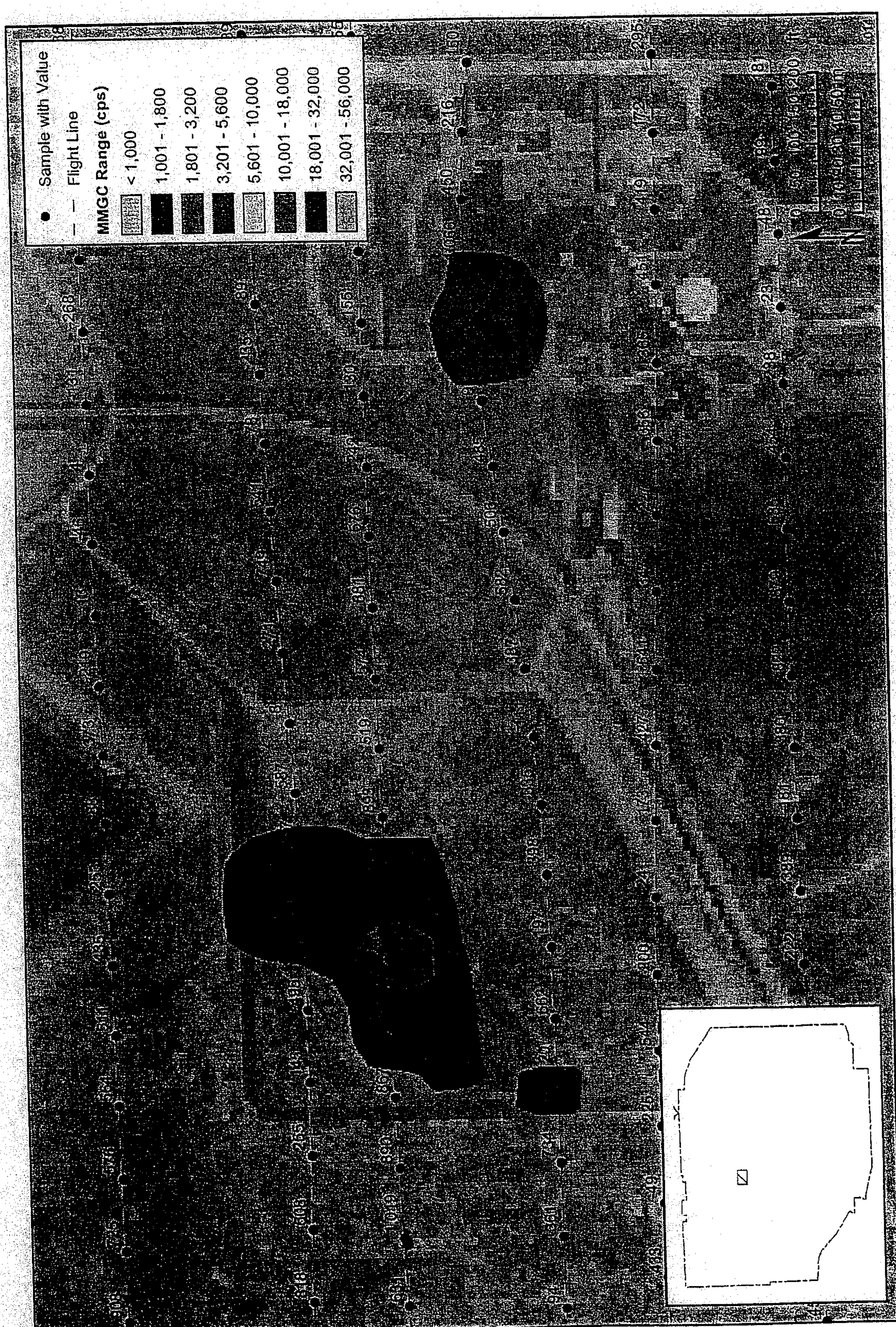


Figure 5-9 Closeup of Coal Pile.

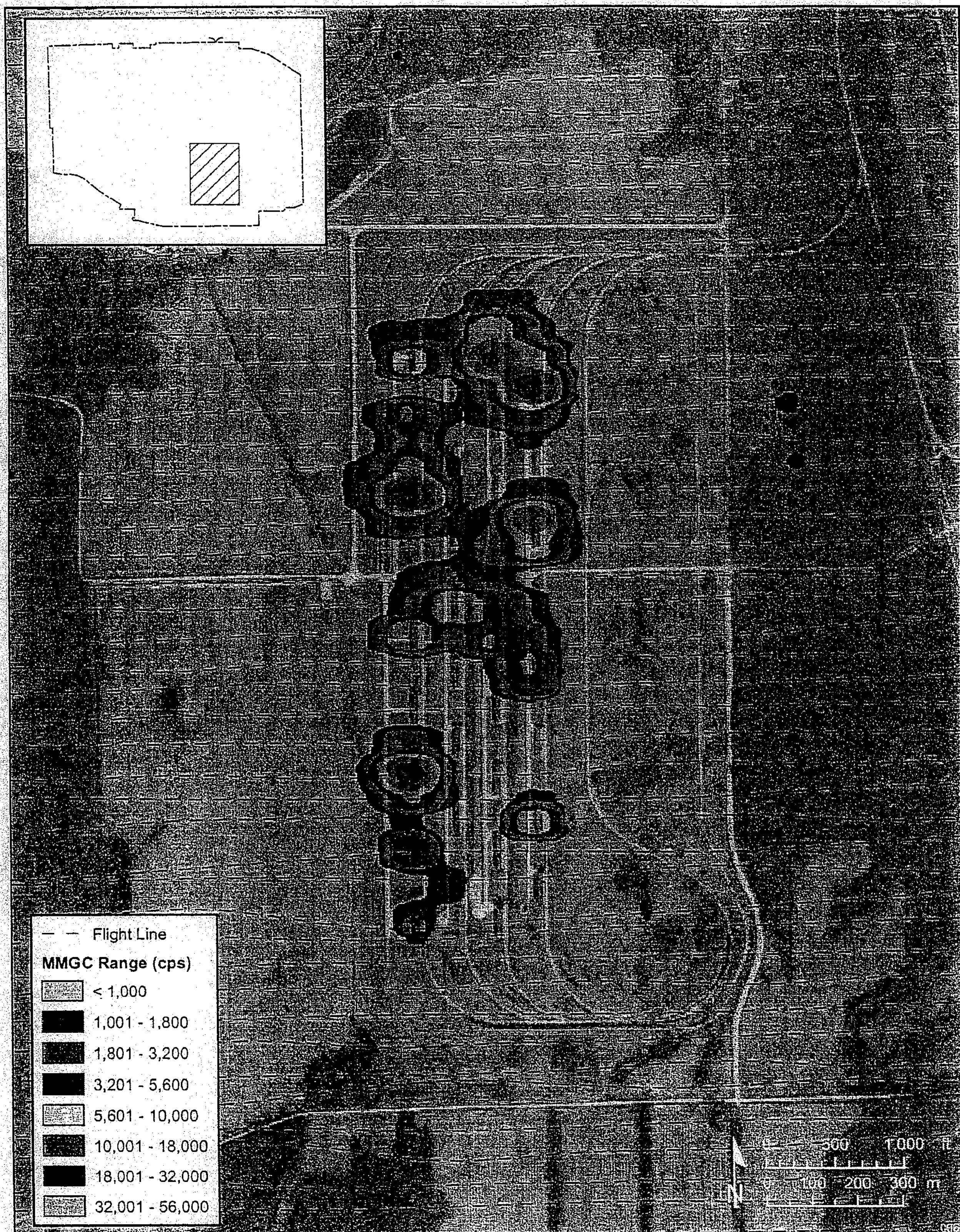


Figure 5-10 Yard E MMGC

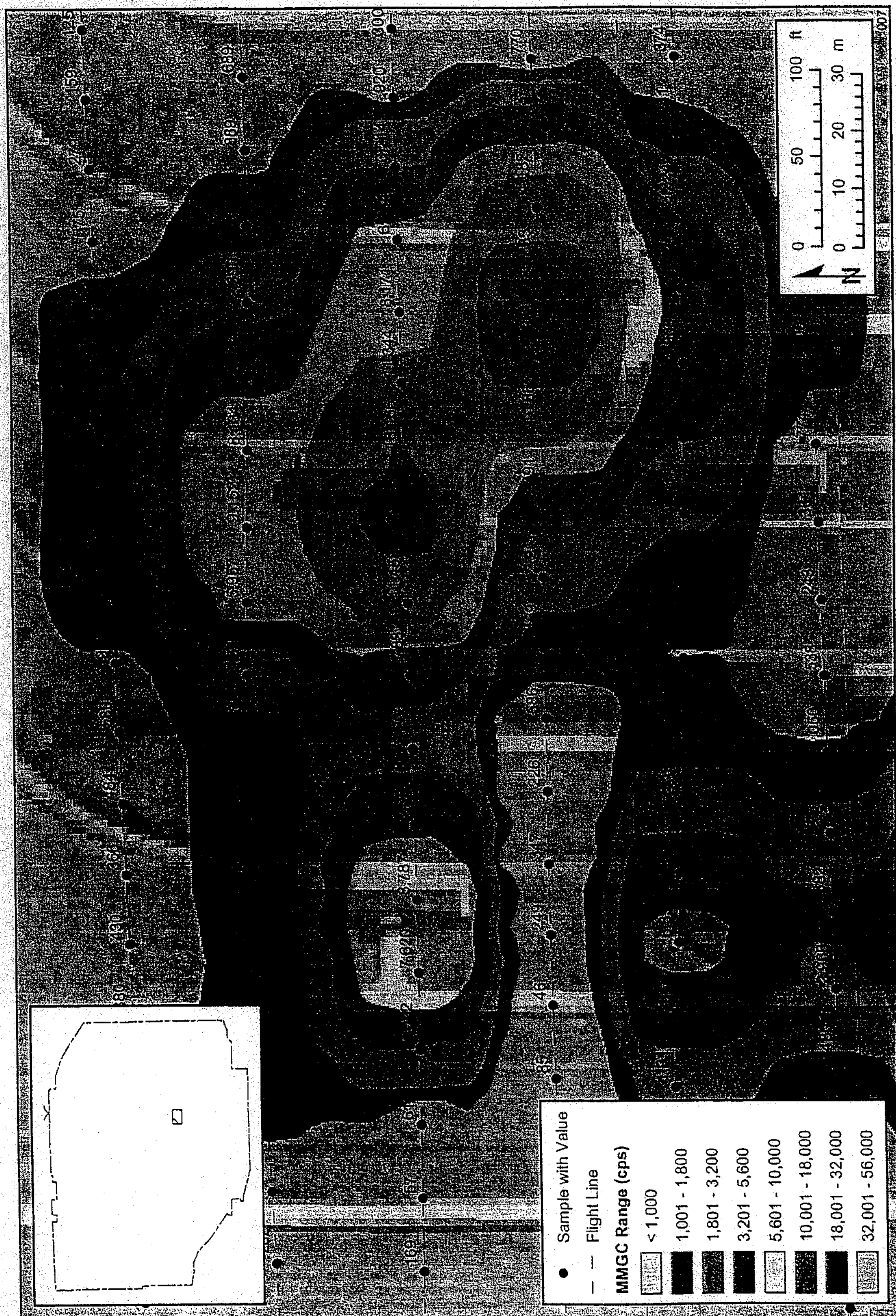


Figure 5-11 MMGC for northern portion of Yard E.

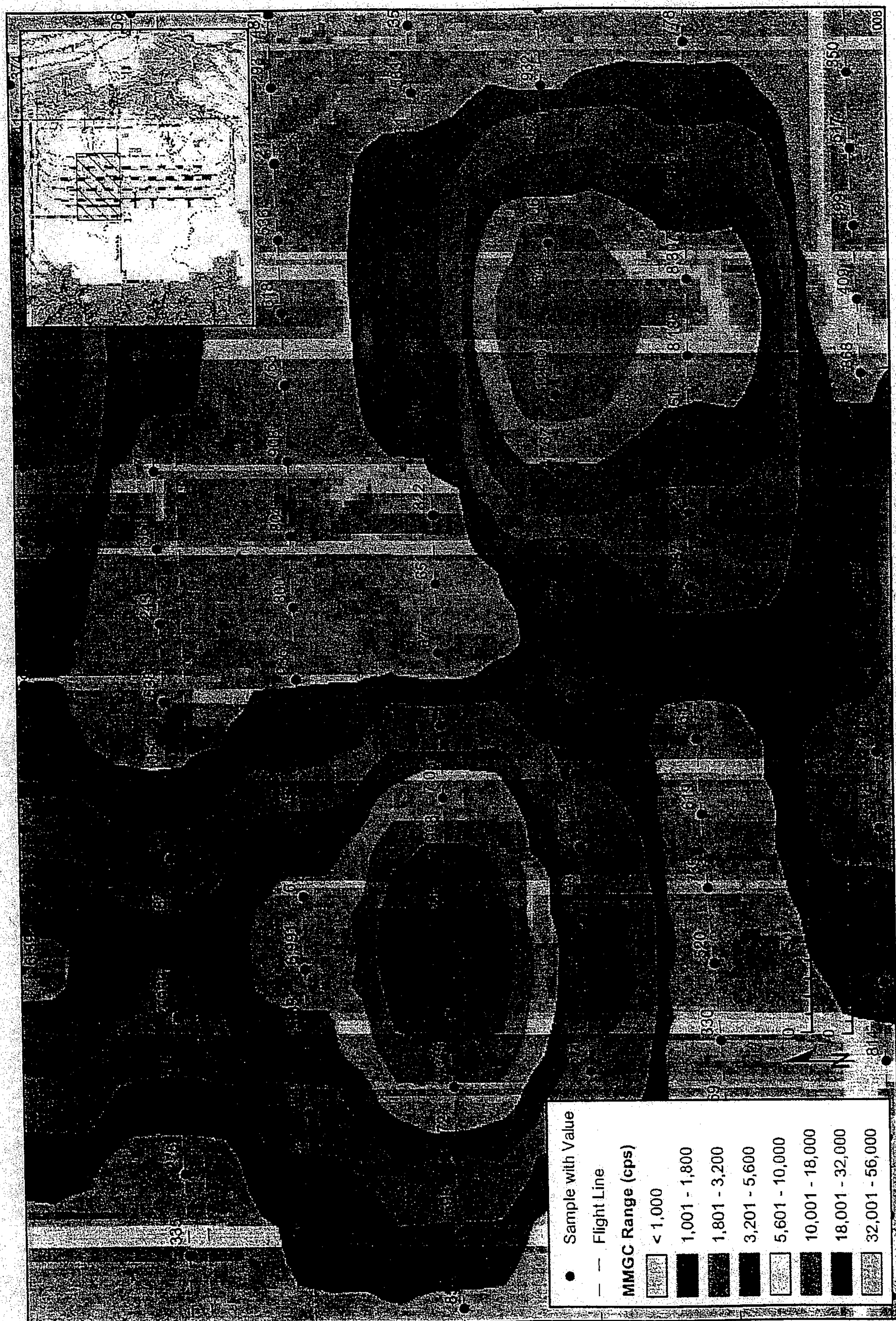


Figure 5-12 MMGC for central portion of Yard E.

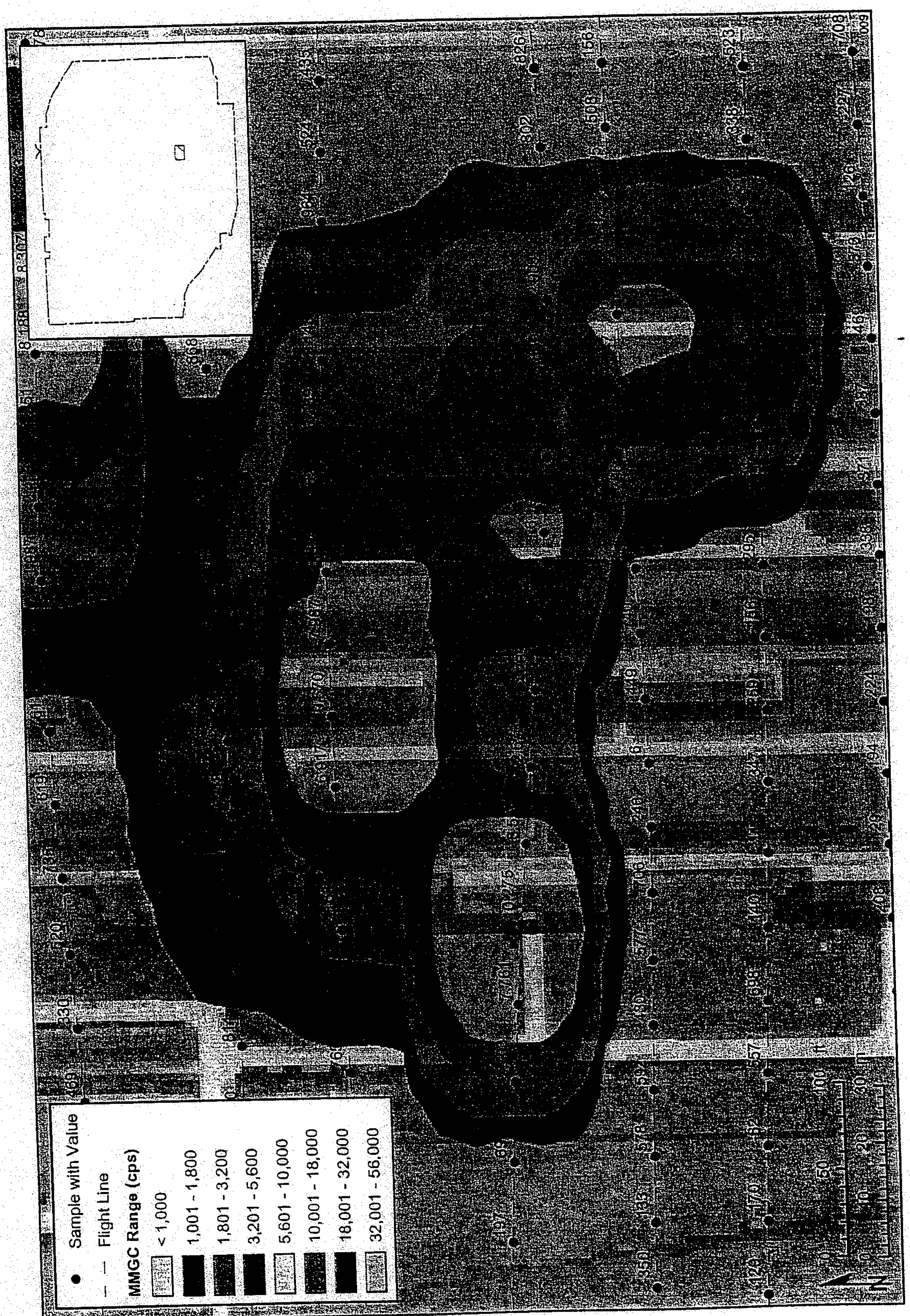


Figure 5-13 MMGC for near southern portion of Yard E.

Chapter 6 Summary

An AMS survey was performed for the IAAAP near Burlington, Iowa from October 22 through October 29, 2002. The survey covered the whole IAAAP area as well as a strip of land about 500-feet wide outside the fence boundary. In the southwest corner, the survey area was extended just beyond the Skunk River. High exposure rates (gross-count data) were observed over the bunkers in Yard E and the Coal Pile at the heating plant. Indications of anthropogenic sources (from the man-made gross count algorithm) were observed over the bunkers in Yard E, the Coal Pile at the heating plant, and at Firing Site 12. Inspections of the gamma-ray spectra over Yard E sites show that depleted uranium is the major anthropogenic radioisotope present. The net spectrum over the Coal Pile indicates an excess of natural uranium compared to the land surrounding the heating plant. The low activity and relatively small area of the Firing Site 12 source area, results in poor statistics for the net spectrum; however, the spectrum is consistent with depleted uranium. No off-post radioactive contamination was found.

Depleted uranium was identified at Yard E, and is the probable radioisotope at Firing Site 12. The radioactivity observed at the Coal Pile is from ^{214}Bi, which is also a ^{238}U progeny. However, this radioactivity results from the natural uranium present in the coal. The data do not indicate the presence of any ^{226}Ra (beyond the amount resulting from the natural uranium in the coal pile). Also, there is no indication for either ^{241}Am (an indicator of plutonium) or ^{137}Cs anywhere on the Plant. In addition, no previously unidentified areas that would require being addressed under FUSRAP, rather than the ER,A account, were identified.

Chapter 7 References

Agency for Toxic Substances and Disease Registry (ATSDR), 2003, *Public Health Assessment Iowa Army Ammunition Plant, Middleton, Iowa*, Available at: http://www.atsdr.cdc.gov/HAC/PHA/iowaarmy/iaa_p1.html#installation, Accessed February 21, 2003.

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Iowa State University, 2003, Iowa Profiles Data for Burlington, Iowa, Available at: http://ia.profiles.iastate.edu/city/city.aspx?CityFips=9550, Accessed February 20, 2003.

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Appendix: Comments and Responses

COMMENTS AND RESPONSES

This appendix contains copies of the comments received on the Draft IAAAP Aerial Radiological Survey report and their responses. The following specific comment sets are addressed:

1. U.S. Environmental Protection Agency (EPA) (Scott Marquess),

2. State of Iowa, Department of Public Health (Dan McGhee),

3. U.S. Army Corps of Engineers (USACE), St. Louis District (Brian G. Harcek),

4. U.S. Army Corps of Engineers (USACE), Omaha District (Luke McCormick), and

5. U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) (Mark Melanson).

Responses to the comments are provided after each comment in bold italics.

U.S. EPA Comments (Scott Marquess):

SENT VIA ELECTRONIC MAIL - 5/27/03

Mr. Rodger Allison
ATTN: SMAIA-INE (Mr. Rodger Allison)
17571 State Highway 79
Middletown, IA 52638-5000

Dear Mr. Allison:

The Environmental Protection Agency (EPA) has reviewed the Draft Iowa Army Ammunition Plant (IAAP) Aerial Radiological Survey (April 3, 2003), which was submitted on April 9, 2003. We offer the following comments on this document:

GENERAL COMMENTS

1. The Radiological Survey Report contains important information regarding potential releases of radiological constituents at the IAAP. The Report, as presented, however, consists primarily of a summary of the efforts and data collected, and does not include sufficient information to independently verify the results. We suggest that the results be provided in a more rigorous format so that an independent assessment of the data could be performed if desired.

***Response:** As discussed in Section 5 of the report, 50,333 data points for gross counts and man-made gross counts were recorded in the aerial survey. Although it is possible to provide this information, appropriate data analyses algorithms would also be needed to perform an independent evaluation of the information. Because of the large number of data points recorded and the need for data analyses algorithms, the information presented in the report is limited to information presented in the various figures, including close-up views of areas in which anomalous counts were recorded.*

SPECIFIC COMMENTS

1. Page 1, paragraph 3 - Please delete the reference to radioactive contamination being the responsibility of the USACE FUSRAP. This is a matter that could be subject to debate and need not be an issue in this report.

Response: Text deleted as requested in the comment.

2. Page 4, paragraphs 3 and 4 - In general, the "Introduction" should describe in some detail the nature of operations and practices at the IAAP that would have generated the radiologic contamination that is the subject of the survey.

Response: Additional information on the source of radioactive contamination added to the report.

3. Page 5 - Please describe why the off-post area is also under consideration for radioactive contamination.

Response: Because off-post areas were specified in the Work Plan for the Aerial Survey, they are included in the Draft Final Report.

4. Please clarify the meaning of the statement in Item #2 on this page.

Response: Item #2 is designed to examine the entire site and off-post areas in order to determine if there is contamination in areas that have been considered to be free of contamination problems. No text change required for the report.

5. Page 8, paragraph 3 - Since explosive contamination in Brush Creek extends beyond where IAAP has exposure control measures in place, the statement that public exposures to contaminants in Brush Creek are "limited" is debatable and should be removed. In fact, more recent sampling of Brush Creek surface water has indicated higher levels of explosives present.

Response: The text "are limited" deleted as suggested in the comment.

6. Page 9, Section 2.4 - The report should provide a more complete discussion of groundwater contamination at and around the IAAP, to indicate the presence of a significant off-post groundwater contamination plume to the south of the IAAP along Brush Creek. Details about the nature and extent of this explosives-contaminated groundwater should be provided. Any sampling for radiologic constituents should also be discussed.

Response: The text describing groundwater contamination, particularly in areas surrounding Brush Creek and a Skunk River tributary and the southern boundary of IAAAP, has been expanded as requested in the comment.

7. Paragraph 2 - Details of the fifth IAAP water supply well, which supplies the MILVAN facility, should be provided.
Response: Because no detailed information is presented for any of the on-site wells, no additional information for the fifth well is provided in the text. Such detail is also beyond the scope of the document.

8. Paragraph 3 - It should be indicated that while all known residents south of the IAAP have been offered an alternate water supply, some of these residents have declined and continue to drink from a private supply well that is contaminated with explosives.

Response: As suggested in the comment, text has been added to the report to indicate that 15 residents declined to be connected to the Rathbun Rural Water System.

9. Page 10, paragraph 1 - We disagree with the statement in the last sentence which indicates that contaminants underlying the IAAP are inaccessible. Suggest you delete.

Response: Text referring to inaccessibility has been deleted as suggested in the comment.

10. Page 16, Section 4 - The report should include a discussion of the Work Plan, and how the field work conducted either complied with or varied from the elements outlined in the approved Work Plan. Further, any impacts on data quality associated with variations in method/approach from the approved Work Plan should be discussed.

Response: The introduction to the report provides a complete link with the objectives of the Work Plan. Because the work performed for the aerial survey complied with the Work Plan and there were no variations in method/approach from the approved Work Plan, no text changes are necessary.

11. Page 16, Section 4.1, paragraph 2 - The report indicates that there was rain at the IAAP at the time of the Survey, however, the rain did not significantly affect the data collected. Please provide a quantifiable, supportable basis for this assertion.

Response: Additional text has been added to Section 4.1 of the report to state that by the time aerial flights started on Saturday morning (October 26, 2002), water from previous precipitation had soaked deep enough into the soil to not interfere with the gamma rays rising from the ground, and there were no areas of standing water observed during the flights that could have interfered with the gamma radiation measured.

12. Page 20, Table 4-2 - This table presents the estimated sensitivity of the survey instrument. As discussed during the preparation of the Work Plan, actual instrument sensitivity associated with the IAAP Survey should be determined.

Response: Table 4-2 presents the actual estimated instrument aerial survey sensitivity for the IAAAP Survey. As mentioned in the text, absolute measurements are possible, but they require much more effort and calibration, and they were not needed for each isotope for the degree of accuracy required for the IAAAP survey. Section 4.7 describes the measurement of the system's sensitivity to DU, the primary isotope of concern at IAAAP.

13. Page 22, Section 4.4.1 - A quantifiable, defensible assessment of data quality should be provided.

Response: A discussion on data quality is provided in Sections 4.4.2 and 4.4.3 of the report.

14. Page 33, Section 4.7 - Please clarify the relationship of the test at the RSL to the Survey work performed at IAAP, and the appropriateness of using the RSL test information for quality control purposes on the IAAP data.

Response: Because attenuation by air of the gamma rays from the test DU sources is very small, results obtained near the Remote Sensing Laboratory in Nevada are equivalent to those that would be obtained at IAAAP. Additional text was added to the report to clarify the use of Nevada data for the IAAAP survey.

15. Page 37, Section 5 - The results should reference the objectives of the Survey as outlined in the approved Work Plan, and discuss how and to what extent these objectives were met by the associated field effort.

Response: All objectives of Work Plan were met in the aerial survey, and discussed in Section 5 of the report. No text changes required.

16. Specific discussion should be included relative to suspected radiological contaminants of concern (COCs) at the IAAP and whether they were detected in the Survey. If the radiologic COCs were not detected, the sensitivity of the instrumentation for detecting these contaminants should be indicated. If the COCs are detected, the source of the detections should be indicated. This is especially important for the detections noted in Yard E. Information should be provided to indicate whether the Yard E detections represent a release to the environment or not, and how this is determined.

Response: A discussion on appropriate detects and non-detects is provided in the Section 5 and summarized in Section 6. Relevant detection limits are described in Section 4. As stated in Section 6, inspections of the gamma-ray spectra for Yard E indicate the presence of DU. It is not possible to determine whether the DU detected in

Yard E represents a release to the environment on the basis of information derived solely from the aerial survey. If desired, a follow-up, ground-based evaluation could be performed to determine the source of the Yard E DU gamma ray signature.

Please contact me at (913) 551-7131 if you would like to discuss our comments.

Sincerely,

ORIGINAL SIGNED BY

Scott Marquess
Project Manager
Federal Facilities / Special Emphasis

Branch

Superfund Division

cc: Kevin Howe, USACE
Dan Cook, IDNR
Dan McGhee, IDPH
Sharon Cotner, USACE

State of Iowa, Department of Public Health (Dan McGhee):

Here are the comments from IDPH on the subject report:

1. This is a report involving radioactivity. Discussions of chemical contaminants are irrelevant. These discussions occur in sections 2.3, "Surface Water," and 2.4, "Groundwater." These discussions should be removed. If, however, the decision is made to keep them, then the whole story should be told. Brush Creek runs, at times at the HAL of 18-20 ppb and is the source of the off-post plume. If there is a description, let it be complete.

Response: For completeness, the discussions on surface water and groundwater have been retained. However, the discussion on groundwater has been expanded as requested in the comment.

2. On Page 13, "roentgen" is not defined correctly. It is not a measure of the amount of radiation absorbed by air, it is a measure of the number of x-rays passing a unit area in a unit time. Moreover, later in that same paragraph, occupational exposures are not given in roentgen, but REM,or fractional parts thereof.

Response: The definition given on page 13 of the document for roentgen is technically correct. However, the following parenthetical definition has been added for clarity: "a roentgen is the quantity of x- or gamma rays that produce $2.58x10^{-4}$ coulombs/kg of air at standard conditions of temperature and pressure". Occupational exposures are typically given in rem, not roentgen, as stated in the text.

U.S. Army Corps of Engineers (USACE), St. Louis District (Brian G. Harcek):

Contractor: ANL/RSL	**Contract No.**	**Document Date:** 3 April 2003
Draft	IAAAP Aerial Radiological Survey - Draft	
	Comments from USACE St. Louis dated 15 May 2003	

No.	pp/§//¶	Comment	Response
1	1/1/3	FUSRAP is not only responsible for radioactive contamination from AEC operations. Recommend that the sentence be revised to clarify this point. (5th sentence)	*Sentence describing responsibility deleted.*
2	3/1/2	Please change the 2nd sentence to read 'A portion of Line 1, the Explosive Disposal Area (EDA) sites, Yards C, G, and L, the Firing Site (FS) area, and other areas as described below, came under the control of the AEC and its contractor, Silas Mason Company (later known as Mason & Hanger-Silas Mason Co., Inc.) (Figure 1-2).'	*Text revised per comment.*
3	3/1/4	It is our understanding that a portion of the wastes were placed in the IDA. Please clarify.	*Text revised by deleting reference to final disposal of contaminants.*
4	4/1/1	Please reword the first sentence to read, 'For the IAAAP AMS survey, portions of the off-post area are also under consideration for radioactive contamination.'	*Sentence reworded per comment.*
5	4/Figure 1-2	Recommend that a figure be provided that shows the flight lines, including those off-post.	*Figure showing the flight path of the helicopter during the survey added. In addition, flight lines superposed on other figures.*
6	5/1/1	Please add 'primarily ^{238}U' after DU, or something similar.	*The word "primarily" added per comment.*
7	8/2.4/3	Please spell-out/add 'MILVAN' to the acronym list	*MILVAN changed to Military Van.*
8	9/2.4/1	Please cite the ER,A ROD as the source of the COC list. FUSRAP COCs have not been agreed upon.	*COC list cited to ER,A ROD as requested in the comment.*
9	13/3.3.1/2	Please add an explanation of 'noise'.	*Text revised to indicate that noise is noise produced by the electronic equipment.*
10	15/4.1/1	The referenced figures do not seem to indicate the off-post areas that were over flown. See comment number 5.	*Figures revised to indicate more clearly the off-post areas flown during the survey.*
11	15/4.1/3	Please explain how the 'rain did not significantly affect' the	*Text added to clarify the effect of rain on the measurements.*

No.	pp/§/¶	Comment	Response
		data. Recommend that the word 'significantly' be deleted, if possible.	***That is, in the absence of standing water, and no continuing precipitation, past rains have no effect on measurements from surface objects.***
12	19/Table 4-2	Please correct the parentheses in the Surface Deposition column. It may be helpful to have the units consistent across the columns, i.e., all in μCi.	***Parentheses corrected in Table 4-2 as requested. Units for the columns not changed. Numbers should not be compared across the columns.***
13	21/4.4.1/1	Recommend that the line spacing distance be added to the discussion in this paragraph.	***A line spacing of 200 ft added at this point in the text.***
14	25/4.6.1/3	In the first sentence, please change 'live' to 'line'.	***Typographical error corrected.***
15	27/Figure 4-4	The figure is hazy, recommend that it be placed into the document in different format.	***Figure enlarged for improved clarity.***
16	32/4.7/1	Please add the dimensions of the DU plates for comparison purposes.	***Dimensions of the DU plates added to the text as requested in the comment.***
17	33/4.7/2	Recommend that 2- and 3σ be explained so that those who are statistically challenged are aware of what is being said.	***Explanations of standard deviation and confidence levels added to the text as requested.***
18	37/Figure 5-1	Recommend adding a label for the coal pile.	***Label for Coal Pile added to the base figures.***
19	44/Figure 5-8	Seems that the area marked '1,017' should be dark blue in color. Recommend that this be explained or changed. Recommend that similar Figures be examined for the similar instances.	***Natural neighbors algorithm for producing the color isopleths modified to incorporate correctly single high value data points that were previously missed. A number of other figures similarly corrected.***
20	49/6/1	The Executive Summary uses 26 October, this section uses 29 October, which is correct?	***The Summary October 26 date changed to the correct value, October 29.***
21	49/6/2	Recommend that the purpose be tied to the conclusion. Suggest the following wording 'No previously unidentified areas that would require being addressed under FUSRAP, rather than the ER,A account were identified.'	***Requested text added to the text as requested.***
22			

U.S. Army Corps of Engineers (USACE), Omaha District (Luke McCormick):

Luke, thanks for your comments. Also, thanks for sending them directly to IAAAP (Rodger Allison).

However, I have some minor feedback regarding the page references provided within your comments. This may be due to the fact that you reviewed a digital copy of the report versus a hardcopy of the report ... and there may be some differences in the page numbering and layout.

> It appears that the text referenced in your 1st comment can be found near the bottom of page 3 within my hardcopy (versus page 7 in your 1st comment).
>
> Section 3.1 begins on page 10 of my hardcopy (versus page 13 in your 2nd comment) ... and Section 3.3 ends on page 14 of my hardcopy (versus page 17 in your 2nd comment).
>
> It appears that the equation #2 referenced in your 3rd comment is on page 25 of my hardcopy (versus page 27 in your comment).

By the way, I assume that you were able to successfully download a digital copy of the report, so I have deleted the files from our FTP server.

Thanks for your assistance.

Kevin Howe

-----Original Message-----
From: McCormick, Luke I NWD02
Sent: Thursday, April 17, 2003 11:23 AM
To: Howe, Kevin M NWO; 'RALLISON@americanordnance.com'
Subject: Comments Iowa AAP Aerial Radiological Survey (Flyover)

*__Comment #1:__ Pg. 7 Suggest the following rewording in the second to last paragraph: "A Preliminary Assessment (PA) performed by the St. Louis District of the USACE indicated the presence of eight radioactive **potentially** contaminated areas."

Response: Second to last paragraph reworded as requested in the comment.

*__Comment #2:__ Pg. 13 through 17 Sec. 3.1 through 3.3 are irrelevant to the report and should be deleted.

Response: Because not all readers are familiar with the terminology used in describing the aerial measurement system and methods, Sections 3.1 through 3.3 are retained for clarity and completeness.

***Comment #3:** Pg. 27 S_f is not in equation 2. Please check the equation and show where S_f is used.

Response:** S_f **appears in Equation 2. No text change required.

USA Army Center for Health Promotion and Preventive Medicine (CHPPM) (Mark A. Melanson):

Rec'd 23 Jun 03

DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

REPLY TO ATTENTION OF

June 16, 2003

Health Physics Program

Subject: Review of Draft Iowa Army Ammunition Plant (IAAAP) Aerial Radiological Survey

LTC Yolanda C. Dennis-Lowman.
Commander
Department of the Army
Iowa Army Ammunition Plant
17571 State Highway 79
Middletown, Iowa 52638-5000

Dear LTC Dennis-Lowman:

In response to your letter of April 8, 2003, Mr. Patrick M. Moscato, Mr. David Alberth, and Mr. Gordon Lodde reviewed the draft IAAAP Aerial Radiological Survey, dated April 3, 2003.

As subject matter experts and representatives of the Commander, U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), we found no discrepancies in the technical content presented.

We provide the following minor editorial comments for your consideration:

- Page vi: Acronyms and Abbreviations, NU.
  Comment: Change "Natual Uranium" to "Natural Uranium".

- Page viii: Units of Measure, KeV.
  Comment: Change "KeV" to "keV".

- Page viii: Units of Measure, Kg.
  Comment: Change "Kg" to "kg".

- Page 7: 2nd paragraph, (ATSPR 2003)
  Comment: Change "(ATSPR 2003)" to "(ATSDR 2003)".

Readiness thru Health

-2-

- Page 19: Table 4-2, Surface Deposition, units provided.
  Comment: Change "(μCi/m$^{2)}$" to "(μCi/m^{2})".

Our point of contact for this review is Mr. Patrick (Mark) Moscato, Health Physicist, USACHPPM. You may reach him at (410) 436-7155/3502.

Sincerely,

Mark A. Melanson
Lieutenant Colonel, U.S. Army
Program Manager
Health Physics

Copy Furnished:
CDR, USA JOINT MUNITIONS COMMAND (AMSJM-SF/MR. CROOKS)
DIR, POPM-SA [MCPO-SA(MCHO-CL-W)]

Response to comments 1 through 5: All the typographical errors mentioned in the comments were corrected.