Per the Federal Facility Agreement for Iowa Army Ammunition Plant, Article X.B.1, the attached document is the final version of the submitted document.

Health Consultation

Environmental Pathway Evaluation for Beryllium and Depleted Uranium

IOWA ARMY AMMUNITION PLANT

MIDDLETOWN, DES MOINES COUNTY, IOWA

EPA FACILITY ID: IA7213820445

DECEMBER 9, 2003

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

BACKGROUND AND STATEMENT OF ISSUES

The Agency for Toxic Substances and Disease Registry (ATSDR) is required by provisions of the Comprehensive Environmental Response, Compensation, and Liability Act to prepare public health assessments (PHAs) of hazardous waste sites either proposed for, or listed on, the National Priorities List (NPL). The Iowa Army Ammunition Plant (IAAAP; originally called Iowa Ordnance Plant) was added to the NPL in August 1990 and in 1999 the PHA was prepared, as required (ATSDR 1999). Prior to the release of the PHA, information became available about the use of radioactive materials at certain locations within the IAAAP that were under the jurisdiction of the Atomic Energy Commission (AEC) during the interval from 1947 to July 1975.

Concerns were raised by members of the public and public officials regarding the presence of radioactive material and the potential for residual radioactivity that may affect the health of both workers and residents of nearby communities and farmlands. ATSDR released the 1999 PHA, which evaluated the potential heath effects resulting from environmental releases of explosives and other substances, and included a recommendation that, when sufficient information became available, ATSDR prepare another document concerning the possible presence of radioactive materials at IAAAP.

In 2000, ATSDR received historical memoranda, letters and other documents for the 1947-1975 time-interval from the Army and obtained draft results of an indoor radiological survey from the Department of Energy (ORNL 2001). Following a review and evaluation of that information, ATSDR prepared a public health consultation (ATSDR 2001). That consultation concluded that, at that time, there was insufficient information available to determine the potential public health effects of the site. The consultation recommended additional environmental surveys and sampling to more fully characterize the extent of radiological contamination, including depleted uranium (DU), at Line 1 and Firing Site 12.

Following the release of the ATSDR (2001) consultation, additional data and information were gathered and released for review and evaluation. Health concerns have focused on releases and exposure to beryllium (Be) and DU and the potential effects those substances may have had on workers or the community members.

ATSDR has reviewed and evaluated the information now available to determine the potential public health effects that may relate to the use and presence of those substances at IAAAP. This public health consultation will focus on the public health concerns about potential *environmental releases* and subsequent human exposure to Be and DU. ATSDR does not evaluate occupational exposures. For each of the concerns addressed below, ATSDR has evaluated potential environmental pathways of exposure to the community and the potential health consequences that may arise from those exposures. A statement of each public health concern is followed by

the *conclusions* that can be drawn at this time and a *discussion* which summarizes the information supporting those conclusions.

Site Description

The IAAAP is a totally fenced and secured, operational, government-owned and contractor-operated facility located on approximately 19,100 acres in Des Moines County, southeastern Iowa (Fig. 1). The Plant, located adjacent to Middletown, Iowa and about six miles west of Burlington, Iowa, is surrounded by rolling prairie with mixed agricultural uses and numerous rural residences (JAYCOR 1996).

The topography of IAAAP is generally flat to gently rolling terrain dissected by shallow, south- to southeast-draining stream channels. The area groundwater also migrates generally to the southeast. The prevailing winds are usually from the west.

Surface water drainages in the Line 1 area flow to Brush Creek on the west side of the Line which then flows southward to its confluence with Skunk River. Surface water drainages in the Firing Site (FS) Area are tributary to Long Creek. Mathes Lake lies along the course of Long Creek and is located near the center of IAAAP; about 1000 feet from the northeast perimeter.

Prior to 1977, water drawn from Mathes Lake and treated in an onsite treatment plant provided the primary drinking water supply for IAAAP. After 1977, drinking water was supplied from the City of Burlington, Iowa Municipal Water Works.

Since load, assemble, and packaging operations began in 1941, IAAAP has used explosives and lead-based initiating compounds to produce a wide variety of ordnance items. The operator of IAAAP (American Ordnance LLC) is currently licensed by the Iowa Department of Public Health License Number 0290-1-29-SM1 for "assembly and demilitarization of staballoy[1] DU penetrators in munitions assemblies and for research and development as described in the application to the Nuclear Regulatory Commission (NRC) dated October 6, 1993." Employee interviews and records searched and reported by TN & Associates (TNA 2002) indicate that DU demilitarization activities at IAAAP may have begun as early as 1975. Interviews further detail that, after Operation Desert Storm, DU rods may have been removed from 120mm anti-armor tank rounds in Line 1, Building 1-85-2.

In 1947 the Line 1 area, portions of the Firing Site (FS) area, the Explosive Disposal Area (EDA) sites, and Yards C, G, and L came under the jurisdiction of the former Atomic Energy Commission (AEC). The Security Command Center (SECOM), the Emergency Response

1 - Staballoy is also known as depletalloy and as D-38.

Command Post (ERC), the Deactivation furnace, Line 3 Warehouse 301, and the North Burn Pads Landfill may have also been utilized. Those areas, totaling perhaps 1,630 acres, became know as the Burlington Atomic Energy Commission Plant (BAECP; COE 2001). Both Be and DU were used in the manufacture or assembly of the finished weapons at Line 1. Components of the devices or compounds were tested at the FS areas. BAECP continued operations at those sites until July 1975. After conducting various site clean-up activities, the jurisdiction of those sites was returned to the Army (COE 2001).

Line 1 (Fig. 2) is approximately one mile long and occupies about 170-190 acres. Line 1 encompasses 250 buildings and related facilities that were all apparently used in some manner in support of the operations related to the fabrication and installation of the shaped charges surrounding the core of the nuclear weapons. IAAAP then partially disassembled the completed weapons for shipping to off-site storage facilities (TNA 2002).

The Firing Site (FS) area (Fig.2) comprises about 450-500 acres and was developed for testing explosives and ammunition. Operations at the FS were centered on the South Firing Site (FS-6) and the North Firing Site (FS-12). FS operations were supported by 15 structures including administrative buildings, storage magazines, component assembly facilities, and observation bunkers.

The EDA is comprised of the East and West Burn Pad areas. Those areas were remediated by soil and ash removal from 1998 to 2000 and are reported to presently represent a low potential for contamination (COE 2001). Within the EDA, the East Burn Pad site was utilized, prior to 1982, for purposes that included the burning or flashing of explosives-contaminated metal, including DU, to remove the explosives residue (COE 2001). There is a possibility that not all of the potentially DU-contaminated ash was removed and residual ash may contribute to surface water and groundwater contamination. ATSDR does not, at this time, have sufficient information to fully evaluate the EDA, although some conclusions can be drawn.

Insufficient data are available at this time to more fully evaluate the Storage Yards C, G, and L, the Deactivation Furnace, Warehouse 301, and the North Burn Pads Landfill. Although the potential for contamination at those locations is judged to be low, the COE (2001) plans additional investigations at these sites. There is no evidence of releases at the SECOM and ERC and no further evaluation of these sites is planned (COE 2001).

COE (2001) concluded that additional investigations of various environmental media (i.e. groundwater, surface soils, and sediments) are needed and are planned to fully characterize the location and degree of environmental contamination at Line 1 and the FS area.

During October 2002, a low-level flyover was conducted to detect evidence of DU or other radiologic contamination at IAAAP and a 500-foot wide swath outside of the Plant boundaries. The results of the flyover were released in April 2003. Those results will be discussed in the

section of this public health consultation dealing with the evaluation of potential environmental releases of DU at BAECP. Additional site investigations are planned for Fiscal Year 2004 (Cotner, personal communication 2002).

Although all planned investigations have not been completed, the additional information that has become available since the release of the ATSDR Health Consultation (March 19, 2001) makes it possible to provide additional evaluation of the potential for exposure of plant workers and nearby residents to environmental releases of Be and DU.

Beryllium: Its Characteristics and Uses

Beryllium is a naturally occurring, silver-grey metal. Lighter than aluminum and more rigid than steel, Be has many unusual properties which make it ideal for several applications, including aircraft and space vehicle structure, x-ray machine assemblage, mirrors, ceramics, metal alloys, and, since the 1950's, nuclear technology including weapons and reactors.

The most significant disadvantage of Be as an industrial material appears to be the toxicity of its dust, fumes, and soluble salts. However, metallic Be has good resistance to alteration or chemical attack and is not easily altered to soluble forms when released to the environment. Most Be in the soils does not dissolve in water and remains bound to the soil particles (ATSDR 2002a, b).

Beryllium is used as the reflector material (or 'pit liner') in most American nuclear weapons and in contemporary thermonuclear 'primaries'. The 'primary', or weapon trigger, consists of three components: the central spherical plutonium 'pit' or core, the Be 'pit liner', and a surrounding high-explosives shaped-charge.

Depleted Uranium: Its Characteristics and Uses

Uranium, the source material for depleted uranium, is a silver-white, lustrous, dense, slightly radioactive element. Natural uranium consists of a mixture of three radioactive isotopes: U-238 (about 99.27% by mass), U-235 (about 0.72%), and U-234 (about 0.0054%). Uranium is present throughout the natural environment in rocks, soil, water, air, plants, animals, and in all humans (WHO 2001a). Because uranium is found in the environment in trace amounts, people can intake it into their bodies via air, food, soil, and water. Uranium contributes to a natural level of radiation in our environment, called background radiation (ATSDR 1999c).

Depleted uranium is a byproduct of the process by which uranium is enriched to produce nuclear reactor fuel and nuclear weapons components. The leftover uranium, DU, by definition, is 40% less radioactive than natural uranium. The DU remaining after removal of the enriched fraction is comprised of about 99.8 % U-238, 0.2% U-235, and 0.0006% U-234 by mass. Reprocessing the uranium in spent nuclear fuel may result in DU containing very small amounts of U-236, plutonium, americium, neptunium, fission products including cesium-137 and technetium-99.

These radio-isotope contaminants in the DU would result in an increase in the radiation dose from uptake in the human body by less than 1% (WHO 2001a).

Depleted uranium is produced in large quantities in the process of enriching uranium and, thus, is widely available and inexpensive to use for a wide variety of civilian and military uses. It is a heavy metal and is twice as dense as lead (Harley et al. 1999). This density provides its value for use in civilian and military applications. The main civilian uses of DU include counterweight and control surface applications in some aircraft, counterweights in some elevators, radiation shields in medical radiation therapy machines, and containers for the transportation of radioactive materials. Military applications include the use in armor piercing munitions and armor plate for military vehicles such as tanks.

STATEMENT OF ISSUES

The following public health issues or concerns about potential releases of beryllium (Be) and depleted uranium (DU) are the focus of this Public Health Consultation.

Concerns:

Have there been environmental releases of beryllium (Be) from industrial operations at BAECP or elsewhere at IAAAP? If environmental releases have occurred, have workers or community members been exposed to Be at levels that would harm their health?

Conclusions:

- Based upon available evidence, there has been no release of Be to the environment at IAAAP. The background levels of naturally occurring Be found in surface soils are not of health concern.
- The source of Be contamination at BAECP was likely associated with the sanding or machining of Be components, or from Be dust found on incoming components. This contamination was detected in samples of interior dust, but is not detected in environmental samples.
- In the past there was a slight potential for incidental worker ingestion or inhalation of naturally occurring Be in dust or soil particles. The levels of naturally occurring Be detected in the surface soils were and are below levels of health concern and would not result in harm to workers' health.
- ATSDR concludes that the uses of Be at BAECP did not represent an environmental health hazard to the nearby communities and residents, including former occupants of the on-post residential area.

Discussion:

During the nuclear weapons assembly process at BAECP, machining and sanding operations of the explosives castings and the Be 'pit liners' (sometimes referred to as 'skulls', or 'helmets') were performed to ensure a proper fit for the final assembly of the weapons. It was this Be sanding process that was, at least in part, responsible for the release of Be dust into the indoor environment of the buildings dedicated to this aspect of the process. Figure 3 provides a generalized, diagrammatic cross-section of a spherical nuclear weapon core showing the relative positions of the components.

ATSDR reviewed the 1970-74 results of Be wipe tests conducted by the BAECP Development Department. The wipe tests were used to detect the presence of Be contamination on indoor, environmental surfaces. Presence of that contamination could suggest potential occupational exposure to Be in the buildings at Line 1 where sampling was conducted and may also suggest potential locations where accidental releases of Be to the environment could have occurred (see Table 1).

In addition to individual sample results recorded in those analytical reports from August 1970 thru August 1974, summary observations were offered that Be levels were highest near the sanding and case areas. Additionally, wipe sampling data prompted the following observation:

> "It is probable that much of the beryllium contamination observed is due to the beryllium dust on incoming component parts which were not adequately cleaned prior to shipment and not from the small sanding operation conducted at the Burlington AEC Plant." (Shahan 1971).

Regardless of the sources of Be contamination, the locations of indoor Be contamination suggests the sites of potential Be releases to outdoor surface soils and possibly to the air near affected buildings. In locations where those surface soils can be eroded by running water from rainfall or historical industrial effluent wastewater, there is also the potential for transportation of the Be contamination to nearby ditches or water bodies.

In the process of collecting data needed for the preparation of the IAAAP Remedial Investigation (RI) report, numerous surface soil samples (0-1-ft depth) were collected and analyzed for a variety of constituent elements and compounds by JAYCOR (1996). Of that total, Be was detected in surface soils (0 -1 ft.) at low levels in about 158 samples collected in the Line 1 area and in 13 samples collected in the FS area. The highest level of Be detected in the Line 1 area was 3.15 mg/kg in surface soils northwest of Building 1-99-5. In the FS area the highest Be detection was 2.36 mg/kg found about 100-feet west of the FS-12 pad. As discussed in the Data Evaluation section, the maximum Be background level was found to be 1.72 mg/kg (TNA 2002).

Subsequent to the JAYCOR investigation, TNA was selected to prepare a Line 1 and Firing Site Supplemental RI for IAAAP. During the process of preparing the Supplemental RI, Be was

detected at low levels in about 170 surface soil (0-1 ft.) or drainage ditch (0-1 ft.) samples (TNA 2002). The highest Be-level detected was 1.91 mg/kg in a drainage ditch east of Building 1-50.

Data Evaluation

About 107 surface soil sample samples were collected by JAYCOR (1996) throughout IAAAP in areas less likely to have been impacted by Plant activities. These samples were collected to determine the natural level (*background level)* of metals, including Be, in the surface soils of the area. Subsequent background surface soil sampling was conducted by TNA (2002) to validate the JAYCOR results and to further evaluate the surface soils to ensure that the background levels determined by the JAYCOR investigation accurately characterized the background levels of metals in IAAAP surface soils (0-1.5 ft. depth). Through this process the maximum Be background level was determined to be 1.72 mg/kg (TNA 2002).

Shaklette and Boerngen (1984) reported the average and range of Be concentrations in soils and other surficial deposits in the conterminous United States as 0.63 mg/kg and <1 to 15 mg/kg, respectively. Thus, the maximum background level determined at IAAAP falls in the lower end of the range of Be background values recorded throughout the U.S.

The background levels of naturally occurring metals in the environment set benchmark levels for detecting the presence of contaminants in the environment. In this case, Be levels detected in surface soils that are above the local, maximum-background level for Be, may be the result of the environmental releases of Be from activities that occurred in BAECP or IAAAP facilities.

A review of the Be analytical data compiled by JAYCOR reveals only 5 detections in the Line 1 area above the maximum-background level (1.72 mg/kg). Those Line 1 detections ranged from 1.8 to 3.15 mg/kg. In the FS area, only one surface soil detection (2.36 mg/kg) was found above the maximum background level.

Similarly, a review of the Be analytical data compiled by TNA reveals only one surface soil detection (1.91 mg/kg, noted above) in excess of the maximum reported background value.

Table 2 provides a summary of the values and locations of the seven surface soil samples that yielded Be concentrations greater that the maximum background value.

In planning their investigation, TNA reviewed site historical records and the data amassed by JAYCOR to determine areas of potential concern. The TNA sampling locations were selected to confirm any elevated levels of metals or explosives reported in the JAYCOR RI (1996). As shown above, the results reported by JAYCOR included a few more samples with values greater than the maximum background value.

The records show that many of the JAYCOR surface soil samples were collected around former sump areas. Those sump areas sampled by JAYCOR were determined to have contaminant contents for various compounds that were above preliminary remediation goal-levels and were subsequently excavated (TNA 2002). Thus, when the same general areas were sampled during the TNA investigation, it appears that the most contaminated soils had been removed. The TNA sampling results seem to reflect the minor level of potential Be contamination not directly related to former sump areas. The Be levels recorded by the JAYCOR sampling are so low that it is difficult to conclude that those samples indicated environmental releases of Be to the sumps.

The locations of the Be detections in the surface soils of the Line 1 and FS areas do not point to clear-cut sources of environmental releases of the element by Plant activities. Rather, the soils data strongly suggest that Be dust or contamination was contained within the buildings or by various safeguard measures that may have been employed at the time.

The levels of Be found in surface soils are not of health concern.

The maximum levels of Be detected in the JAYCOR RI studies are only slightly elevated above the natural background level. The locations sampled do not suggest any potential areas or "hot-spots"of Be contamination. Thus, *ATSDR concludes that, in the past, there was a slight potential for incidental worker ingestion of naturally occurring Be in dust or soil particles. The levels of Be detected in those soils were and are below levels of health concern and would not result in harm to worker's health.* Incidental oral ingestion of Be-contaminated dust or soil from IAAAP would result in a dose several orders of magnitude below the 1 µg/kg/day Minimal Risk Level (MRL) derived by ATSDR (2002a). The MRL is an ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects.

Lacking any evidence of transportation of Be from a Line 1 or Firing Site area source to locations near the IAAAP boundaries, *ATSDR concludes that the uses of Be at those locations did not result in any significant environmental releases of the element and do not represent an environmental health hazard to the nearby communities and residents, including former residents of the on-post living area.*

Concern:

Have workers or community members been exposed to environmental releases of depleted uranium (DU) at levels that would harm their health?

Conclusions:

- The evidence available at this time does not indicate that environmental releases of DU occurred from BAECP activities conducted at Line 1.

- The opportunity for human exposure to infrequent and minor environmental releases of DU at FS-6 was extremely limited and does not represent a health threat.
- The localized environmental release of DU-bearing dust and fragments during hydroshot testing or subsequent remediation activities at FS-12 have not resulted in any exposure to the nearby communities or residents, including the former residents of the on-post residential area.
- During the 1965-1975 interval there was a limited opportunity for incidental, inhalation exposure of workers to DU-bearing dust in close proximity to FS-12 immediately following the detonation of a hydroshot. Subsequent site clean-up activities may have re-suspended some DU particles and some incidental, inhalation exposure of remediation workers may have occurred.
- There is a limited potential for incidental, inhalation exposure to DU for workers involved in munitions testing or site maintenance at FS-12 during the interval from 1975 until 2000.
- Burning or flashing of explosives-contaminated DU at the East and perhaps the West Burn Pads did not create an air pathway of exposure for nearby communities or residents, including the former residents of the on-post residential area.
- Vegetation in the Burn Pads area would not have been contaminated with DU and any subsequent burning of the vegetation would not contribute to airborne DU.

Discussion:

Exposure to DU: Potential Health Effects

Because of the many similarities between naturally occurring uranium and DU, many of the findings on the potential health effects from human exposure to uranium are also useful to more fully understand the potential effects that might arise from exposure to DU. Furthermore, because of uranium's chemical properties, the adverse health effect associated with its exposure is one of a heavy metal, that is, its effect on the kidneys. ATSDR (1999b) has derived a Minimum Risk Level (MRL) for oral ingestion of uranium of 2 µg/kg/day and an inhalation MRL of 8 µg per cubic meter in air.

On the average, about 90 µg of uranium exist in the human body from normal intakes of water, food, and air. The average intake of uranium by adults is estimated to be 460 µg from ingestion and 0.59 µg from inhalation. Most (>95%) of the uranium entering the body by ingestion or inhalation is not absorbed by the body, but is eliminated in the feces. Of the uranium that is absorbed in the blood, approximately 67% will be filtered by the kidneys and excreted in the urine within 24-hours; this amount increases to about 90% in a few days. Typical gut absorption rates for uranium in food and water are about 2% for soluble uranium compounds and about 0.2% for insoluble uranium compounds (WHO 2001a).

No human cancer of any type has ever been demonstrated to be a result of exposure to uranium or DU (ATSDR 1999b).

Long-term studies of uranium miners have reported some impairment of kidney function depending upon the level of exposure. There is some evidence, however, that this impairment may be transient and that kidney function returns to normal after the exposure to elevated levels of uranium has ceased (WHO 2001a). In other studies of uranium miners, an increased risk of lung cancer has been reported, but this has been attributed to exposure to radon decay products and lung irritants present in the mines.

In recent years, extensive and intensive national and international investigations have been conducted on the potential human health effects that may arise from civilian exposure resulting from the production, storage, or uses of DU, as well as to exposure that may result from military applications of DU-bearing ordnance on the battlefields such as the Balkans, Kuwait, and Iraq. Excellent, comprehensive overviews of those investigations on potential human health effects are summarized in sources such as the WHO DU monograph and fact sheet (WHO 2001a, b) or in U.S. Defense Department informational papers or exposure reports on DU (see DOD 2000, 2001).

Concerns about potential health effects have been voiced by some military veterans that were either exposed to DU by friendly-fire or potentially exposed to DU while in close proximity to, or entering previously neutralized targets. Concerns have also been raised by civilian populations that have occupied or utilized former battlefield areas potentially contaminated by DU.

Individuals can be exposed to DU in the same ways as to natural uranium, i.e. through inhalation, ingestion, or dermal exposure. The relative contribution from each of those pathways to the total DU-uptake is a function of the physical and chemical character of DU, as well as the level and duration or frequency of exposure.

Potentially, DU has both chemical and radiological toxicity with the two important target organs being the kidneys and the lungs. Long-term ingestion of uranium, or DU-contaminated drinking water, or incidental ingestion or inhalation of DU particles in the soil, may result in damage to those organs.

The chemical toxicity of natural uranium and DU are identical (ATSDR 1999b). Because the radioactivity of DU is about 60% of natural uranium, its radiologic toxicity is correspondingly less. The primary radiation types produced by DU are alpha particles, blocked by the skin, and beta particles, blocked by clothing and footwear (external exposure). Gamma rays are a highly penetrating energy, but the amount of gamma radiation produced by DU is very low. However, in the case of internalization of DU, both alpha particles and the corresponding beta particles from the decay products in DU become an issue for health concern.

The available evidence indicates that the highest levels of potential human exposure to DU occur in the battlefield setting. Measurements of DU contamination taken by the United Nations Environmental Programe at sites in Kosovo, where DU-bearing munitions were used, indicate contamination of the ground surface was localized to within a few tens of meters of the impact site (WHO 2001a). In the extreme case, when "hard" armor-plating, such as a tank, is pierced by DU munitions, the penetration process pulverizes much of the projectile which explodes into burning fragments when it hits the air on the other side. The result is an airborne aerosol cloud of DU-oxide particles within the target vehicle. Estimates vary, but perhaps about 10-20% of the DU-projectile mass is aerosolized. These DU-oxide particles formed inside the target are respirable but with time the oxides adhere to the surrounding metal surfaces or are released to the atmosphere through openings. The available evidence indicates that in the "worst-case" hard-armor impacts, the DU particles do not vaporize (DOD 2000, Moses 1978).

Follow-up exposure investigations of potential troop exposures to DU conducted after the Gulf War found that the highest levels of potential human exposure to the respirable DU-oxide dust are inside the target vehicle. It was also found that those particles can be re-suspended by re-entry, reclamation, or repair of the vehicle, resulting in a secondary source of potential exposure (DOD 2000).

While respirable DU-oxide dust can be released to the environment, the total volume appears to be small and localized in close proximity to the target vehicle or point of impact. Conceivably, the very small DU particulate could disperse at greater distances from the source. However, deposition of these fine particles would be widely scattered and, consequently, measurable amounts of DU would not occur in localized areas distant from the source (ATSDR 1997).

Taken together, estimates made of the maximum DU battlefield dose and the ongoing, follow-up medical evaluations of those individuals subject to the greatest potential exposure to DU-oxide aerosols, do not indicate that Gulf War veterans experience DU intakes high enough to affect their health (DOD 2000).

Thus, even on the battlefield, the evidence suggests that the use of DU munitions produces localized soil contamination ranging from coarse fragments to very-fine particulate sizes. Any health effects to be attributed to the DU contamination would then be due to the ingestion or inhalation of the DU-particulate matter. Insoluble DU particles, 1-10 μm in size, tend to be retained in the lungs, possibly for many years. WHO (2001a) suggests that such a long-term exposure may result in radiation damage to the lungs or possibly even lung cancer if a high enough radiation dose was sustained for a prolonged period.

Like most metals, uptake from dermal exposure is negligible and is not likely to result in adverse health effects. Even direct contact of DU with the skin for several weeks is unlikely to produce radiation-induced inflammation of the skin. However, with the passage of time, the decay products of the DU will result in a higher skin dose and a greater potential health concern.

Follow-up studies of veterans with DU fragments embedded in wounds have shown detectable DU in urine, but without apparent health consequences (WHO 2001a). There is no data to suggest that skin cancer results from dermal contact with uranium or DU dust (ATSDR 1999b, DOD 2001).

The Use and Occurrence of DU at IAAAP

Because of its many unique properties, DU has been used for various purposes during the operations conducted at the BAECP portion of the IAAAP. The following sections describe the areas where DU was used and a description of that use. Together, this information helps to identify potential pathways of environmental release of DU.

The occurrence or distribution of DU or other radiologic contamination at IAAAP was evaluated during low-level flyovers conducted during October 2002. The draft results of the IAAAP Aerial Radiological Survey prepared by the Argonne National Lab (ANL) in conjunction with the Remote Sensing Lab and were released on April 3, 2003 (ANL 2003).

ATSDR reviewed the survey findings presented in that draft report. This document discusses the technical aspects of the aerial remote sensing used to discern radiological contamination present at the IAAAP. For the survey, the entire facility was surveyed as well as a 500-foot wide area outside the IAAAP boundary. The survey methods used were similar to other methods used, with modification since 1958.

Based on this survey, radiation was detected in three areas of the facility. These were the coal pile, Yard E, and Firing Site 12. Through computer enhancement, the radiation detected was then limited to man-made radiation (radioactive material enhanced or modified through man-made activities). Those sites, in which this type of radiation was detected, were then limited to Yard E and Firing Site 12 (most likely attributed to the DU). The radiation detected in the coal pile was from the uranium and other radioactive materials normally found in coal.

Yard E is identified as a storage area for licensed DU storage for DU munitions and is not, therefore, a site of release of DU to the environment. Firing Site 12 will be discussed in more detail later in this document. The aerial survey did not detect any man-made radiation outside these areas or outside the confines (public areas) of the plant.

Line 1

On Line 1, from 1947 until about 1962, the first step of the production process was the casting of baratols (the spherical-shaped, explosive charge that surrounds the nuclear weapon's core) and the machining of the casts to ensure a precise fit (TNA 2002; COE 2001). Both baratols and "hydroshot" explosive charges (the small hemispheres of explosives used to test the performance of the explosives; see the description below in the FS Area discussion) may have contained a thin

sheet of DU (COE 2001). The machining or grinding of these components may have released small quantities of DU to the machining room environment or to any resultant waste. It is reported (COE 2001) that the waste material from this process was taken to the Explosives Disposal Area burn pads for disposal by burning.

Beginning in about 1962, the process of casting the baratols was replaced by a new process which involved pressing explosives in a plastic state into molds (TNA 2002). Thus, the need for machining was eliminated and, to the extent that a thin sheet of DU may have been involved in the baratol at this time, the potential for DU release to the environment from this production phase was eliminated.

In 1973, the AEC announced that Line 1 would be phased out of operation. In 1975, Line 1 operations ceased and were relocated to the AEC Pantex facility, near Amarillo, TX. As part of the close-out process, the AEC conducted a radiologic survey of the areas and the buildings it occupied and determined that no real property contained residual radioactive contamination above standards in existence at that time (COE 2001). The Buildings surveyed included: 1-2 thru 1-7, *1-11 thru 1 -13, 1-19, 1-40, 1-63 thru 1-67, 1-77*, and 1-137-2 (building numbers in italics are buildings that were also surveyed later for DOE [ORNL 2000]).

ORNL (2000) conducted a review of historical records in preparation for performing an indoor radiological survey. The COE (2001) also conducted a records review and interviews of previous BAECP employees to gather information for their Preliminary Assessment. Those investigations identified several Line 1 Buildings that may have been, or were, involved with the use or storage of DU or other radiologic materials. In 2000, ORNL detected levels of residual DU contamination in Buildings 1-11, 1-12, 1-61, and 1-63-6. The DU contamination detected in Building 1-61 was restricted to a plastic storage pan (COE 2002).

DU or other radiologic contaminants were not detected in the Line 1 area by the October 2002 airborne survey (ANL 2003).

ATSDR concludes that *the evidence available at this time does not indicate that environmental releases of DU occurred from BAECP activities conducted at Line 1.*

Firing Site Area

The Firing Site (FS) Area was developed for the testing of explosives and ammunition. The South and North Test Fire Areas, now collectively termed the FS Area, were apparently originally established to support BAECP operations. In addition to the perimeter fence surrounding IAAAP to limit unauthorized access to the site, the FS Area is also fenced to further restrict access. There is also a locked gate blocking vehicular traffic to FS-12. Operations at the South Firing Site centered around FS-6, and at the North Firing Site Area at FS-12.

FS-6 was constructed in 1948 and this FS is still used for ordnance testing. Quality control testing of explosives (plane-wave testing) was conducted at this site until these test-shot procedures were moved to FS-14 in 1972. Apparently, most of the explosives testing at FS-6 did not contain any radioactive elements, however, some explosives may have contained a thin sheet of DU (COE 2001). This DU would have been pulverized or fragmented upon detonation of the shot. During a walk-over conducted by the COE, DU was discovered in the earthen berm at FS-6. However, the source of this DU is unclear (COE 2001). Little is known of the testing activities conducted at FS-14, but information gathered in interviews indicate that testing of small amounts of conventional explosives occurred there (COE 2001).

DU or other radiologic contaminants were not detected in the FS-6 area by the October 2002 airborne survey (ANL 2003).

Based upon the available evidence, ATSDR concludes that *the opportunity for human exposure to infrequent and minor environmental releases of DU at FS-6 was extremely limited and does not represent a health threat.*

FS-12 was constructed in 1964. Both TNA (2002) and COE (2001) report that during the interval between December 1965 and December 1973, a series of specialized tests called "hydroshots" were conducted exclusively at FS-12. Hydroshots tests were conducted to test the hydrodynamic performance of the shaped explosives used in the ordnance produced at BAECP.

The explosive device used in the hydroshot testing was assembled in FS-5 and comprised of an explosive charge shaped as a hemisphere, about half the size of a basketball and weighing from 1-3 kg (2.2 to 6.6 lb). The explosive charge was surrounded by a DU ring about 1-2 inches in height and weighing about 22 kg (48.5 lb). The purpose of the DU ring was to simulate the hydrodynamic conditions in a fully spherical weapon (TNA 2002; COE 2001). A generalized cross-section of the explosive device is given in Figure 4.

The records indicate that a total of 701 hydroshot tests were performed between 1965 and 1973. These tests reportedly dispersed about 4,000 kg (8,820 lb) of DU that was scattered as far as several hundred feet from the FS-12 firing point (TNA 2001). Detonation of the shaped charge pulverized the containing ring of DU, yielding DU-debris ranging in size from coarse fragments to very fine particles.

The standing operation procedure was to collect DU fragments after each test and dispose of them as radioactive waste. Because fine particles of DU were also produced during the test detonation, the AEC conducted air monitoring during some of the tests. A concentration of radioactive material of 5.3E-13 microcuries per milliliter ($\mu Ci/ml$)[2] was measured at FS-12 (COE

2 - The units microcuries per milliliter ($\mu Ci/ml$) are reported in (COE 2002) but the typical concentration units for air are microcuries per cubic centimeter ($\mu Ci/cc$). These two units are equal to one another.

2001). Because DU is very dense and will settle to the ground more rapidly than other particulate material, the air monitoring did not detect any DU-radioactivity at the IAAAP boundaries.

In 1975 the AEC performed a fairly limited site clean-up at FS-12 by excavating a few inches of soil in an area which encompassed the area immediately surrounding the firing site and a "couple hundred square meters" around the periphery of the site. The removed soil was tested and disposed of as radioactive waste in an offsite facility in Illinois. Although testing results did not find radioactive contamination at that time, numerous DU fragments have been found recently at FS-12 (COE 2001).

The site was turned over to the Army in 1975 for testing of conventional weapons, not including DU. Then, in 2000, DU fragments were discovered and the Army discontinued use of the site (TNA 2002). It is theorized that larger fragments of DU penetrated the surface soils a few inches, shielding them from previous detection or site remediation. Subsequent site maintenance, or the natural process of frost-heave, then exposed the DU fragments now found on the surface of the FS-12 site (COE 2001). There is a limited potential for incidental, inhalation exposure to DU for workers involved in munitions testing or site maintenance at FS-12 during the interval from 1975 until 2000. Because DU fragments are so dense, the potential for re-suspension of those fragments or particles is low. Therefore, the potential for incidental, inhalation exposure during the 1975-2000 interval is limited.

As previously noted, DU was detected at FS-12 by the October 2002 airborne survey (ANL 2003).

Based upon the available evidence, ATSDR concludes that *during the 1965-1975 interval, there was a limited opportunity for incidental, inhalation exposure to DU-bearing dust in close proximity to FS-12 immediately following the detonation of a hydroshot.* The observation bunker at the site would have helped to minimize employee inhalation exposure to DU fragments and particles released during detonation of the explosive charge. Because DU particles are very dense, airborne particles would quickly settle to the ground in the nearby area. *Subsequent site clean-up activities may have re-suspended some DU particles and some incidental, inhalation exposure may have occurred. Also, there is a limited potential for incidental, inhalation exposure to DU for workers involved in munitions testing or site maintenance at FS-12 during the interval from 1975 until 2000.*

The conditions created by the detonation of a hydroshot are far less severe than those created by the penetration of hard armor by a DU penetrator. Thus, it is likely that little if any DU-oxide aerosols were created during the detonation of a hydroshot. Additionally, surface soil disturbance during remediation activities or subsequent maintenance operations conducted at FS-12 had, and have, the potential to result in incidental inhalation exposure. However, ATSDR does not know if standard precautions were in place to minimize such potential exposures in the past. ATSDR recommends that, *if future investigations indicate that soil removal or surface disturbing*

activities must be undertaken in this area, care should be taken to minimize the generation of dust and the potential re-suspension of respirable particulate.

Because drinking water was drawn from Mathes Lake prior to 1977, there is a slight potential that the drinking water supply may have been contaminated with DU. No data is available to evaluate the potential for past groundwater contamination, therefore, *ATSDR also recommends that groundwater sampling be conducted, down-gradient to the FS area, to determine if any DU-related, radiologic contamination exists in the shallow groundwater.*

ATSDR concludes that the available evidence indicates that *the localized environmental release of DU-bearing dust during hydroshot testing or subsequent remediation activities at FS-12 has not resulted in any exposure to nearby communities or residents, including the former residents of the on-post residential area especially considering the distance from the firing site area to residential areas on and off the facility.*

The Explosive Disposal Area (EDA) - East and West Burn Pads

The East and West Burn Pads are located within the EDA. They are located in the northeast corner of IAAAP, approximately one mile from the installation boundary.

The East Burn Pads covered an area of about three acres and consisted of eight raised-earth pads. Each pad was enclosed on three sides to minimize lateral migration of wastes and the complex was enclosed within a 12-acre fenced area. Operated by BAECP until 1975 and by the Army until 1982, the pads were used for open burning or flashing of explosives-contaminated metal, including DU, to remove the explosive residue (COE 2001). The site was remediated in approximately 1998 by soil removal. The excavated soil was placed in landfill cells at the Inert Disposal Area (IDA).

The West Burn Pads, located near the eastern pads, consisted of two pads measuring about 50 feet by 15 feet. Those pads were operated by BAECP, and subsequently by the Army, from 1949 to 1982. These pads were also used to flash explosives-contaminated metals. ATSDR has not been able to determine if explosives-contaminated DU wastes were flashed at this site. The wastes generated at this site, from 1950 to 1975, were deposited in the West Burn Pad Landfill also located within the IDA (COE 2001).

A standing operation procedure for waste from Line 1 activities (AEC, No. 41, Rev. 2, April 1971) cited by the COE (2001) states that for wastes involving DU, the burned ash containing excessive alpha contamination was collected in plastic bags and shipped to Pantex for burial. Although not documented, ATSDR assumes that this order covers the waste generated at both the East and West pads and that, because the cited order is apparently a revision of a previous order, similar provisions were made for the collection and disposal of wastes prior to 1971.

Site remediation activities, consisting of the removal of about 12,000 cubic yards of soil from the East Burn Pad area, were completed in 1998 (COE 2001). Those soils were placed in the IAAAP IDA. The West Burn Pad area was remediated by soil removal in 2000 and the soil was also placed in the IDA (COE 2001). The soils from the West Burn Pad area were subjected to gross radiological screening and no radioactive material was discovered.

The research reports summarized by DOD (2000) include several important conclusions which are useful to ATSDR's evaluation of whether potential pathways of exposure were created by activities conducted at the East and West Burn Pads.

First, when flashing explosives-contaminated metal, the burn consumes little oxygen because the explosive supplies its own. Explosives, by design, burn very rapidly and, thus, the duration of the burns are quite short unless other combustible compounds are present. Although no data are available on the temperatures of the Burn Pad fires, because DU requires a burn temperature of 3000° C and because the combustion is so rapid, we conclude that little, if any, of the DU was oxidized. In the absence of violent explosions, few particles are created that can be caught up in the smoke and thermal currents generated by the fire.

It is unknown if fine particles of DU resulting from machining or sanding processes conducted at Line 1 may have been transported to the Burn Pads for flashing. Because DU particles are very dense, any particles that could become airborne would quickly settle to the ground in the nearby area.

Finally, the extreme conditions cited above that are known to result in the production of DU-oxide aerosols, are absent and it is not likely that DU-oxide aerosols were generated at the Burn Pads. For these reasons, ATSDR concludes that *the flashing of explosives-contaminated DU at the East and perhaps the West Burn Pads did not create an air pathway of DU exposure to nearby communities or residents, including the former residents of the on-post residential area.*

It is unlikely that information can be developed that might permit ATSDR to fully evaluate the potential for incidental, inhalation exposure of the personnel that conducted the burns at the pad sites or for those workers that conducted periodic site clean-up of those burn pads. However, given the information developed about exposure to DU in the military setting, it is unlikely that adverse human health effects would arise from those potential, incidental exposures.

DU is minimally transferred from soil to vegetation. The uranium bioaccumulation coefficient factor (CF) for the transfer from soil to vegetation ranges from 0.01 to 0.0001 (http:www2.nau.ed; see also Baes et al. 1984). The range in the CF values is affected by the soil acidity: greater uptake with increasing levels of acidity. Plant species also vary in their bioaccumulation of metals or other substances from the soils surrounding their roots. Given the very low CF values for uranium and, therefore, for DU, ATSDR concludes that *any DU*

contamination of nearby vegetation in the Burn Pads area would have been very minimal and any subsequent burning of the vegetation would not contribute to airborne DU.

The DU oxides that are formed during a fire have very low solubility, but in time some small fraction may be leached and potentially migrate to groundwater. The degree of potential contamination of groundwater is, of course, influenced by the total quantity of DU oxides left in the surface soil, the length of time the oxides reside in the surface soils, the depth to groundwater, and other environmental factors.

At this time, information is not available that would permit an evaluation if there was an environmental release of DU to groundwater from activities conducted at the burn pads. For this reason, *ATSDR recommends that groundwater monitoring be conducted downgradient of the East and West Burn Pad areas of the EDA for evidence of DU contamination resulting from the burning of explosives-contaminated DU at these sites.*

COMMUNITY CONCERNS

Some family members of former BAECP employees and some health professionals have expressed a concern that worker's families could have been exposed to Be dust. This potential route of off-site migration of Be dust is evaluated below.

Concern:

Were family members or acquaintances of former BAECP employees exposed to Be-contaminated dust brought home on the worker's clothing?

Conclusion:

- Based upon the available evidence, changing and showering facilities were available and procedures were in place to minimize or eliminate the potential off-site migration of Be dust. ATSDR concludes that the workers' street clothing, worn home after their work shift, was not a potential source of exposure of family members or acquaintances to Be dust.

Discussion:

The existence of change houses is documented in the Preliminary Assessment prepared by DOD (2001). A total of three change houses were used at BAECP. The first change house in use was apparently in building 1-137-2. In the 1950's, when the capacity of BAECP was expanded to two production lines, two additional change houses (1-137-1 and 1-137-4) were utilized. Although the available documentation does not specify when change house 1-137-2 was first utilized, it

was apparently used prior to the plant expansion in the 1950's and may have been utilized from the start-up of production in 1947.

Change house 1-137-2 served personnel in building 1-07. Change house 1-137-1 served workers in buildings 1-10, 1-12, and 1-13; and 1-137-4 served workers in buildings 1-05-1, 1-05-2, 1-100, 1-40, and 1-61. Those change houses were equipped with showers and were located near the parking lots and the cafeterias. Their locations would have facilitated and encouraged good personal hygiene and changing at the end of the work shift.

In order to determine how the change houses were utilized at BAECP, ATSDR contacted personnel at the Pantex facility located near Amarillo, Texas (when Line 1 operation ceased in 1975, those operations were transferred to the Pantex plant). John Campbell of the Pantex plant reported that BAECP workers changed into overalls for their work shift and then removed their overalls and showered prior to changing into personal clothing and departing the Line (Campbell, personal communication, 2003). Some security guards have noted that their uniforms required dry cleaning, and that they did not change clothes before and after their shifts.

An example of the current health and safety guidance for workers in occupations that involve exposure or potential exposure to Be dust is given in the Defense Programs Beryllium Good Practices Guide (LLNL 1997). That guidance specifies different levels of protection for workers depending upon the potential level of exposure to Be dust, but consistently requires the use of protective overalls in the work areas. The guidance also requires the use of showering facilities prior to changing into street clothing. This guidance, although more detailed, is similar to what ATSDR has learned about the use of the change houses and showering facilities at BAECP.

It is unknown at this time what provisions were made for laundering the overalls. Potentially, incidental inhalation exposure to Be dust could occur during the laundering process. This potential exposure may represent an occupational exposure but is not an environmental release.

ATSDR concludes that *the workers' street clothing, worn home after their work shift, was not a potential source of exposure of family members or acquaintances to Be dust.*

CONCLUSIONS

In addition to the conclusions listed previously in the Be and DU sections of this public health consultation, ATSDR has formulated the following overall conclusions regarding the potential environmental releases and human exposure to Be and DU at IAAAP, the BAECP, and the surrounding area:

- The information available at this time indicates that there have been no *environmental releases* of either Be or DU from activities conducted at IAAAP or the BAECP that were at levels that would result in adverse human health effects to residents of the facility or those living outside the facility boundary. Therefore, ATSDR places IAAAP in the No Apparent Public Health Hazard category. No Apparent Public Health Hazard is a category used in ATSDR's public health assessments and consultations for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
- ATSDR will continue to review the results of current and proposed environmental investigations and, if the findings of those investigations indicate that there have been or are pathways of human exposure to contaminants at levels of potential health concern, ATSDR will evaluate the new data and information and release its findings.
- Prior to 1977, the drinking water for IAAAP came from Mathes Lake. After 1977, drinking water was supplied by the City of Burlington, Iowa Municipal Water Works. No data is available to indicate whether or not DU-related, radiologic contamination exists in the shallow groundwater.
- ATSDR will attempt to obtain written documentation of the changing and showering requirements used at BAECP and any other related information that would permit further evaluation of this potential source of exposure.

RECOMMENDATIONS

- ATSDR recommends that the future investigations conducted by the COE- FUSRAP include groundwater monitoring downgradient of the East and West Burn Pad areas of the EDA for evidence of DU contamination resulting from the burning of explosives-contaminated DU at these sites.
- ATSDR also recommends that groundwater sampling be conducted, down-gradient to the FS area, to determine if any DU-related, radiologic contamination exists in the shallow groundwater.
- ATSDR recommends that, if future investigations indicate that soil removal activities must be undertaken in areas of DU contamination, care should be taken to minimize the generation of dust and the potential re-suspension of respirable DU particulate.

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Acronyms and Abbreviations

AEC	Atomic Energy Commission
ANL	Argonne National Lab
ATSDR	Agency for Toxic Substances and Disease Registry
BAECP	Burlington Atomic Energy Commission Plant
Be	beryllium
CF	bioaccumulation coefficient factor
COE	U.S. Army Corps of Engineers
DOD	Department of Defense
DOE	Department of Energy
DU	depleted uranium
EDA	Explosive Disposal Area
ERC	Emergency Response Command Post
FS	Firing Site
FUSRAP	Formerly Utilized Sites Remedial Action Program
ft.	foot
IDA	Inert Disposal Area
IAAAP	Iowa Army Ammunition Plant
lb	pound
mg/kg	milligrams/kilogram
µCi/cc	microcuries per cubic centimeter
µCi/ml	microcuries per milliliter
µg	microgram
µg/kg/day	micrograms per kilogram per day
µm	micrometer
MRL	Minimal Risk Level
NPL	National Priorities List
NRC	Nuclear regulatory Commission
ORNL	Oak Ridge National Laboratory
PHA	Public Health Assessment
RI	Remedial Investigation
SECOM	Security Command Center
TNA	TN & Associates
U	uranium
WHO	World Health Organization

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Figures

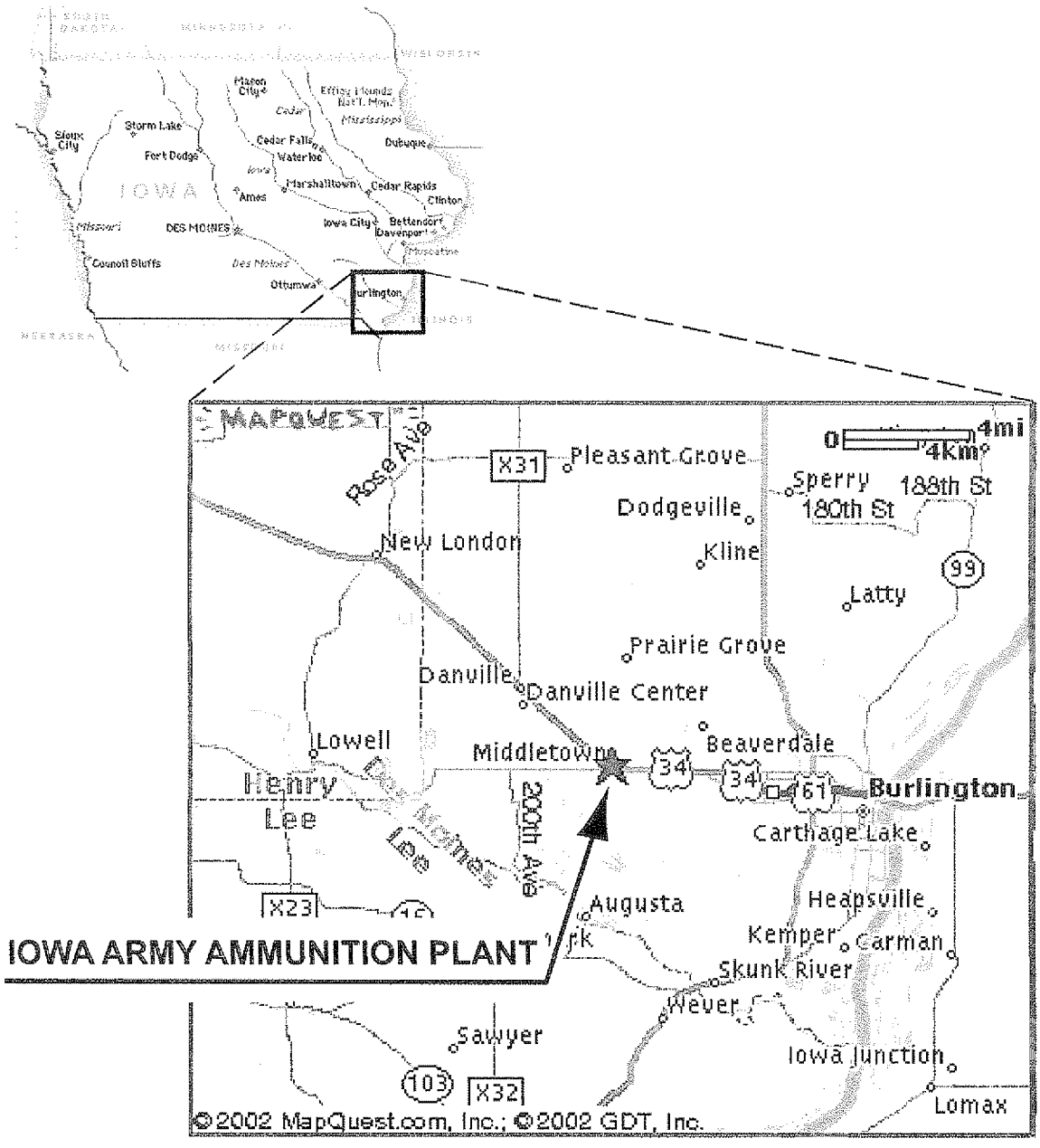

Figure 1. Geographic Location of Iowa Army Ammunition Plant–Middletown, Iowa.