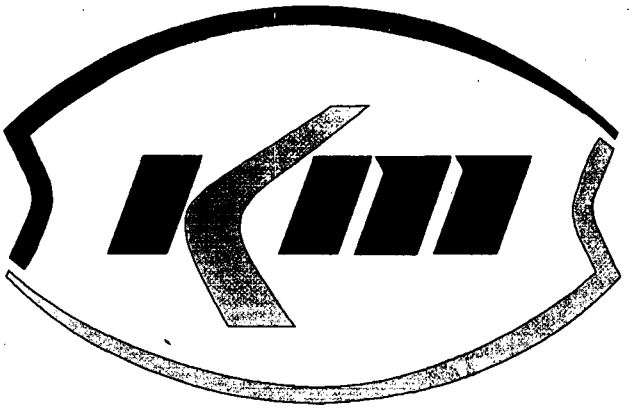
# KERR-McGEE CORPORATION



# Response to NRC Comments on the Cimarron Corporation Final Status Survey Plan for Phase II Areas for Cimarron Corporation's Former Nuclear Fuels Fabrication Facility Crescent, Oklahoma

License No. SNM-928
Docket No. 70-0925

January 28, 1997

CIMARRON CORPORATION
CRESCENT, OKLAHOMA

**CIMARRON RESPONSES TO**
**NRC Staff Comments Dated October 31, 1996**
**on the "Final Status Survey Plan for Phase II Areas for**
**Cimarron Corporation's Former Nuclear Fuel Facility**
**at Crescent, Oklahoma."**

**Comments on the Final Status Survey Plan for Phase II Areas of Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma.**

**NRC Comment:**

Additional information is needed in several areas of the Final Status Survey Plan (FSSP). These areas include:

**1.(a)** Surface Sampling for Open Land Affected Areas: Section 6.4.2 (pages 14-15) discussed soil sampling without referring to the number of samples within a 100 $m^2$ grid area. Section 8.5 (page 21) indicated that "soil sampling frequency will be specified in Cimarron Special Work Permit(s) and, where practicable, surface soil samples will be collected at a 5 meter interval." It is unclear if Cimarron will adopt a gridding/sampling protocol (for open lands affected areas) consistent with NUREG/CR-5849 (e.g., Figure 4-4), or will adopt a different sampling protocol. Therefore, additional information is needed to explain the surface sampling methodology within the 100 $m^2$ grid area.

**RESPONSE:**

Cimarron Corporation has adopted a gridding/sampling protocol for Open Land Affected Areas which is more conservative than NUREG/CR-5849. All Open Land Affected Areas within the Phase II Area have been or will be gridded and sampled on a 5m x 5m grid system. Any portion of an open land affected area which cannot be surveyed and sampled on a 5m x 5m grid will be identified in the Final Status Survey Report.

**NRC Comment:**

**1.(b)** Subsurface Gridding/Sampling for Open Land Affected Areas: Volumetric

activity of soil was outlined in Section 6.4. Section 8.5 discussed surface soil sampling and locations. Will subsurface samples be collected? If subsurface samples are not proposed to be collected in some or all of the Phase II areas, please provide documentation to support the conclusion that the potential for subsurface contamination is low. The documentation should include a review of process knowledge, remediation survey results and characterization results, as applicable.

**RESPONSE:**

Sub-surface samples have been collected on a 10m x 10m grid interval in numerous "Open Land Affected Areas" located within Phase II Sub-Areas. The sub-surface sample data generated for these areas is contained in the October, 1994 Characterization Report. Several examples are listed below:

- **Burial Area #1** This data is presented in Section 7.0 of the October, 1994 Cimarron Radiological Characterization Report and Drawings #91POB1SS-0 through #91POB1SS-4.

- **East Sanitary Lagoon and West Sanitary Lagoon** This data is presented in Section 11.1 of the October, 1994 Cimarron Radiological Characterization Report and Drawings #90POSLSS-0 through #90 POSLSS-4. (Note: The samples were collected on a 5m x 5m grid).

- **Drain Lines from Closed Sanitary Lagoons to Cimarron River and from Uranium Waste Pond #1 to the Cimarron River, including the Siphon Line** This data is presented in Section 15.0 (C) & (D) of the October, 1994 Cimarron Radiological Characterization Report and Drawings #94POERSS-0 through #94POERSS-4.

In addition, the following is stated in Section 2.0 (page 2) of the Final Status Survey Plan for Phase II Areas:

> "Based upon historic knowledge of site operations and the characterization work completed to date (presented in the 1994 Cimarron Radiological Characterization Report), the site has been divided into affected and unaffected areas. Affected areas are areas in which residual contamination has been identified or where historical information indicates the potential for radioactive contamination. Unaffected areas are areas which are not expected to contain residual contamination. The designated affected and unaffected areas are shown on Drawing No. 95MOST-RF3."

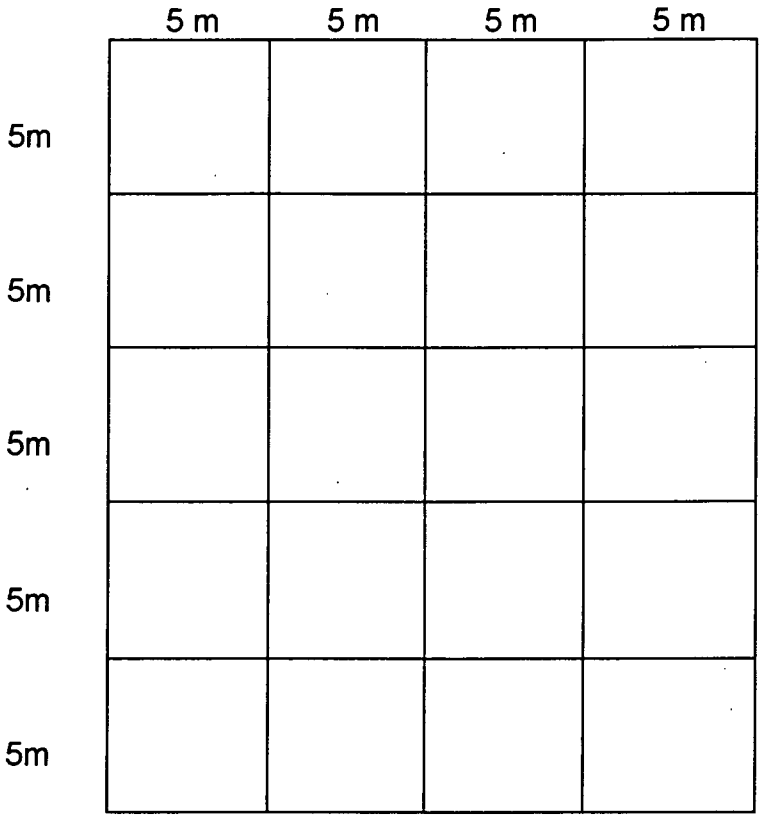
The documentation of the review of process knowledge, remediation survey results and characterization results are contained in the 1994 Cimarron Radiological Characterization Report. Therefore, the information provided above, as well as the information contained in the 1994 Characterization Report, supports the conclusion that the potential for sub-surface contamination in Phase II Open Land Affected Areas is low.

Cimarron Corporation does not intend to sample to depth Phase II open land affected areas which have previously been sampled, or are in the process of being sampled to depth in accordance with Draft NUREG/CR-5849. Two of these areas are Burial Area #1 and the East & West Sanitary Lagoons. ORAU performed extensive sub-surface characterization of these areas after all remediation activities were completed by Cimarron Corporation. NRC approved of the backfill of these areas with clean backfill material (Amendment #9 to License SNM-928, dated December 28, 1992). These two ORAU reports are listed below and copies are also attached:

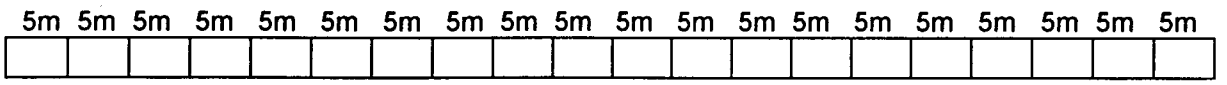
- Confirmatory Radiological Survey Former Burial Ground, Cimarron Corporation Facility, Crescent, Oklahoma. Performed by B. M. Smith, Oak Ridge Associated Universities, July, 1992.

- Confirmatory Radiological Survey of the Sanitary Lagoons of the Cimarron Corporation Facility, Crescent, Oklahoma. Performed by B. M. Smith, Oak Ridge Associated Universities, November, 1991.

However, Cimarron Corporation will collect additional sub-surface samples in open land affected areas within Phase II which do not meet the criteria described in the paragraph above. For these open land affected areas, Cimarron Corporation will collect and analyze subsurface samples, composited at one foot intervals, down to a maximum depth of 4 feet (or rock). The subsurface samples will be collected at a frequency of one out of every twenty (20) 5m x 5m grids located within open land affected areas within the Phase II Area. One sample location out of every twenty (20) 5m x 5m grid areas (see example below) equates to one (1) sample location for every 500 square meters (to be located approximately in the mid-point of each 500 square meter area as some areas may not conform to this configuration). Therefore, a total of twenty (20) locations would be sampled for each 10,000 square meter area for open land affected areas (i.e. 20 sample locations with 4 composite soil samples per location), or a total of 80 soil samples for each 10,000 square meter grid area located within the Phase II open land affected areas.




Drainage ways, road ways and former pipeline runs located in open land affected areas will be sampled on a frequency of 1 sample location for each 100 meters in length (see below), or a total of 4 samples down to a maximum of 4 feet or rock for each 100 meters in length. As stated above, Cimarron Corporation does not intend to sample to depth Phase II open land affected areas (drainage ways, road ways and former pipeline runs) which have previously been sampled, or are in the process of being sampled to depth in accordance with Draft NUREG/CR-5849.




**NRC Comment:**

**1.(c)** Hot-Spot Averaging Approach: Section 6.4.2 (page 14) indicated that "unaffected area hot-spot averaging will be performed for all locations, within 100 $m^2$ grid areas, which contain soil concentrations in excess of 30 pCi/g total uranium above background." It should be noted that NUREG/CR-5849 states that "identification of hot-spots for individual locations with activity levels in excess of 75% of the guideline values requires reclassification of the area as "affected"." In addition, the plan

should justify the hot-spot averaging approach for affected areas specifically when the sampling protocol within the 100 $m^2$ area is inconsistent with NUREG/CR-5849 (Figure 4-4). The FSSP should also discuss whether areas of elevated activity will be actually determined based on discrete sampling within the grid or will be assumed to have a constant value (e.g., 25 $m^2$ based on 5m x 5m grid sampling). If subsurface contamination is identified as a possibility in a given area, hot-spot averaging for subsurface media should also be discussed based on a well defined subsurface sampling protocol.

**RESPONSE:**

Cimarron Corporation agrees that the "identification of hot-spots for individual locations with activity levels in excess of 75% of the guideline values requires reclassification of the area as affected." The statement in section 6.4.2 contained a typographical error and the word "unaffected" should have been "affected". As stated in the response to comment #1(a) above, "Existing characterization data utilized in the Final Survey Plan (Phase II) will either be sufficient to meet the criteria contained in NUREG/CR-5849 or will have a technical justification explaining why the data is determined to be adequate" (section 8.0, page 19). "Hot-Spot" averaging was also addressed in the Cimarron Corporation response (dated 9/11/96) to the NRC comments on the "Final Status Survey Report for Phase III, Sub-Area L (Subsurface)".

**NRC Comment:**

**2.** The FSSP (Section 8.0) discussed the characterization survey and soil sampling data without addressing the quality of data to be used in the final survey. Characterization data are acceptable for inclusion in the Final Status Survey (FSS) report. However, the quality of data (e.g., accuracy, precision, uncertainty, and minimum detectable limits) to be used in support of the FSS must be provided.

**RESPONSE:**

Section 7.4 of the FSSP provides a description of the Cimarron Quality Assurance Program which has been utilized during the Final Status Survey for Phase II areas. Section 7.4 (Quality Assurance) was modified based upon comments from NRC staff during the review and approval process for the FSSP for Unaffected Areas - Phase I (submitted to NRC on August 9, 1995) and Cimarron Corporation's responses to the NRC comments (letter dated November 13, 1995) which were approved by the NRC on April 23, 1996 (License Amendment No. 13). As stated in the

response to comment #1(a) above, "Existing characterization data utilized in the Final Survey Plan (Phase II) will either be sufficient to meet the criteria contained in NUREG/CR-5849 or will have a technical justification explaining why the data is determined to be adequate" (section 8.0, page 19). NUREG/CR-5849 (Section 4.1.1, pages 4.2 - 4.5) addresses Quality Assurance under "General Considerations for Survey Planning".

Information regarding Quality Assurance for instrumentation is also addressed in Table 8.1 (page 20). Cimarron Corporation will specifically address Quality Assurance in the Phase II Final Status Survey Report and/or reference previous submittals to the NRC which outlined such Quality Assurance information. Cimarron Corporation believes that their Quality Assurance Program is more than adequate for fulfilling all the requirements contained in Draft NUREG/CR-5849 with respect to performing Final Status Surveys.

**NRC Comment:**

**3.** Section 6.3 (page 10) of the FSSP indicated that Warehouse Building #4 was never used to process radioactive materials. However, contamination was discovered (during additional surveys conducted in 1993) in several small areas, after the building was used for non-nuclear purposes. Please identify the source(s) of contamination on the floor of Warehouse Building #4. In addition, please define the extent of contamination.

**RESPONSE:**

The following information is contained in Section 14.1 (Uranium Warehouse Building #4) of the October, 1994 "Radiological Characterization Report for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma":

> "The warehouse is a sheet-metal building (50 ft. x 160 ft.) which was never used to process radioactive materials. However, fuel assemblies were inspected and assembled for a short period of time within this building. Cimarron personnel requested permission from the NRC on September 18, 1979 to decontaminate the warehouse and use the building for coal liquefaction processing. Approval was granted on December 28, 1979 by the NRC. However, a license amendment was not issued. This building is covered under Uranium License SNM-928. The NRC's December approval letter stated:

"We agree with your proposal to decontaminate the building to below the NRC guidelines for release for unrestricted use prior to using it for non-nuclear activities; however, we will not eliminate this area as a place of use under your license since it is an integral part of the Cimarron facilities".

Final release surveys were completed on the inside and outside surface of this building in 1980. The results for the floor survey showed an average fixed activity of 500 dpm/100 $cm^2$ alpha with a maximum fixed activity of 2,254 dpm/100 $cm^2$ alpha. The walls, fixtures and other surfaces showed an average fixed activity of less than 500 dpm/100 $cm^2$ alpha with a maximum fixed activity of 2,500 dpm/100 $cm^2$ alpha. The NRC gave approval on March 28, 1980 to use the Coal Building for non-nuclear purposes based upon these surveys.

The survey conducted in 1980 was for alpha only. Additional surveys were conducted in the Coal Building in 1993 for both alpha and beta/gamma. This survey revealed several small areas with elevated levels of beta activity in the concrete floor which required decontamination. An alpha survey performed at the same time showed a maximum fixed activity of 500 dpm/100 $cm^2$ and average of 200 dpm/100 $cm^2$."

As stated above, the survey performed in 1980 was only for alpha. The survey performed in 1993 was for alpha and for beta/gamma. Again, as stated above, the 1993 survey revealed only a few small areas with elevated levels of beta/gamma activity (not alpha) in the concrete floor.

Attachment 1 depicts where the beta contamination was located and provides a description of the survey results. The contamination was ostensibly tracked into Warehouse Building #4 from the Uranium Yard Area and from the Uranium Building. The Uranium Yard Area and the Uranium Building were the sources of the contamination. These beta activities ranged from an average of 760 dpm/100 $cm^2$ to a maximum of 1,430 dpm/100 $cm^2$.

**NRC Comment:**

**4.** The release limits for paved surfaces were discussed in Section 6.4.1 (pages 13-14) of the FSSP. It appears that the criteria (e.g., dpm/100 $cm^2$) from NRC's "Guidelines For Decontamination of Facilities and Equipment Prior to Release For Unrestricted Use or Termination of

Licenses for Byproduct, Source, or Special Nuclear Material", August, 1987, will be used. It should be noted that NUREG/CR-5849 treats paved surfaces as open land areas. Please provide the basis for using a surface activity criterion (e.g., dpm/area) rather than a volumetric open land criterion (pCi/g) and selecting averaging over 100 $m^2$ area.

**RESPONSE:**

This issue was addressed by the NRC staff in their comments on the Cimarron Decommissioning Plan. The following comment regarding release limits for paved surfaces was presented by NRC staff on the Cimarron Decommissioning Plan (NRC letter dated July 11, 1996) and the Cimarron Corporation response to the NRC staff comment was submitted to the NRC on September 10, 1996. The NRC staff comment and the Cimarron Corporation response are provided below in response to this comment:

**"#6 NRC Comment - Page 1-7, Paragraph 3**

Are the surface contamination criteria from NRC's "Guidelines for Decontamination of Facilities and Equipment Prior to release for Unrestricted Use or Termination of License for Byproduct, Source, or Special Nuclear Material," August 1987, being used for exterior paved surfaces? If so, please justify averaging over 100 $m^2$ as opposed to the 1 $m^2$ area recommended in the August 1987 guidance.

**RESPONSE:**

For exterior paved surfaces, the August 1987 surface contamination criteria from NRC's "Guidelines for Decontamination of Facilities and Equipment Prior to Release from Unrestricted Use" are being utilized by Cimarron Corporation. However, the activity is averaged over 100 $m^2$ as opposed to 1 $m^2$. NUREG/CR-5849 treats paved surfaces as open land areas (See "Open Land Surveys", NUREG/CR-5849, Section 4.2.3, page 4.16). Systematic grid surveys for open land areas are performed on a 10 m x 10 m grid as noted in Figure 4-4 (page 4.17) in NUREG/CR-5849. This treatment of paved surfaces as "Grounds" is also discussed in Section 4.3.7, page C-25 of NUREG/CR-5849.

Draft NUREG/CR-5849, Section 6.5.3 states that "Direct measurements of surface activity levels are performed on paved surfaces, following the procedures described in Section 6.4.3 for building surfaces." Draft NUREG/CR-5849, Section 6.4.3 contains the statement that "Experience

has shown that a 1 minute integrated count, using a large area (100 $cm^2$) detector, is a practical field survey procedure and will provide detection sensitivities that are below most guideline levels."

**NRC Comment:**

**5.** Please confirm that all drain lines have been excavated and will be surveyed as part of the FSS. Please describe the sampling methods used to delineate the boundaries of the affected areas along and below the drainage lines. Please provide the data to demonstrate that the boundaries of these affected areas have been adequately defined.

**RESPONSE:**

All of the drain lines within Phase II Areas have been excavated, surveyed (both the drain lines and the excavation itself) and removed from all of the Phase II Sub-Areas (F, G, H, I, and J) with the exception of one small section of a sanitary drain line (no longer in use) located beneath Warehouse Building #4 and the sanitary drain line to the septic drain field which is currently in use. All excavations and surveys performed during the drain line removals involved sampling and surveys until Option #1 levels were achieved. The one small section of sanitary drain line (no longer in use) located beneath Warehouse Building #4 has been decontaminated and surveyed for free release. The survey was completed in March of 1993 and all of the survey results were below 2,000 dpm/100 $cm^2$ alpha. This is discussed in detail in Section 15.0(G), page 15-5, of the October, 1994 "Radiological Characterization Report for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma".

Other drain lines located within the Phase II Sub-Areas were removed at various stages throughout the decommissioning process. For example, the drain lines from the Closed Sanitary Lagoons to Cimarron River and from the Uranium Waste Pond #1 to the Cimarron River, including the Siphon Line were removed in June of 1985. Surveys were performed on the Drain Lines, excavated area and the excavated soils at that time. The areas where these drain lines were previously located were again sampled to depth (0 to 4 feet) at 10 m intervals along their length in 1994. (See Section 15.0 (C) & (D) of the October, 1994 Cimarron Radiological Characterization Report and Drawings #94POERSS-0 through #94POERSS-4).

The sanitary sewer system (i.e. laterals, septic lines, etc.) currently in use was installed to replace the former sanitary lines and septic tank that were

used from site construction until 1994. All other components of the former sanitary sewer system were removed with the exception of the small section located beneath Warehouse Building #4.

Drawing No. 95MOST_RF3 depicts large "unaffected area buffers" on each side of the drainage lines located within Phase II Sub-Areas. These "unaffected area buffers" were not included as part of the Phase I Sub-Areas in order to ensure that a large "buffer" was in place between the "Unaffected" Sub-Areas in Phase I and the "Affected" drainage lines located in Phase II Sub-Areas. The sampling and survey data for these "affected areas" (i.e. drainage lines) and "unaffected area buffers" is still being collected. The "unaffected area buffer" will be sampled as part of the Phase II, Sub-Area Unaffected Area. This data will be provided in the Final Status Survey Report for Phase II.

**NRC Comment:**

**6.** Section 6.3 (page 10) of FSSP indicated that "two soil samples showed americium contents that were above background but below NRC's guidelines." However, in Section 6.1 (Identification of Contaminants), americium was not included among the contaminants. Please provide information regarding the concentration and source(s) of americium.

**RESPONSE:**

Section 6.3, (pages 8 - 10) referenced in this comment referred to a FONSI and Notice of Opportunity for Hearing which was issued by the USNRC (Federal Register, Volume 58, No. 28, pages 8432 through 8434, February 12, 1993). Listed below is the section of the Phase II Plan which is referred to in this comment:

> "The FONSI and Notice of Opportunity for Hearing appeared in the Federal Register on February 12, 1993. The following section appears in items (2) and (3) on page 8432 of this Federal Register notice:
>
> (2) There is limited contamination of the surrounding soils. The average uranium content of the exterior soils is two to three times background levels but about two orders of magnitude below NRC soil guidelines for disposition of contaminated soils with no restrictions. The average plutonium content of the exterior soils is indistinguishable from background and over two orders of magnitude below NRC soil guidelines for disposition of contaminated soil with no restrictions. Two soil samples

showed americium contents that were above background but about one order of magnitude below NRC soil guidelines for disposition of contaminated soil with no restrictions. The average gamma dose rate at 1 meter above the soil is indistinguishable from background.

(3) The surface contamination levels of plant interior and exterior surfaces are, on the average, three orders of magnitude below NRC decontamination guidelines."

Cimarron Corporation is unclear as to the purpose of this comment. Cimarron Corporation referenced the MOFF Plant and Yard Area due to the fact that this area falls within Phase II, Sub-Area "I". The following is also provided on page 8 of the Phase II Plan:

"The following was stated in the February 5, 1993 NRC letter:

> The staff has determined that (1) all special nuclear material relating to this license has been properly disposed, (2) reasonable effort has been made to eliminate residual radioactive contamination, and (3) a radiation survey has been performed, and confirmed by the NRC, which demonstrates that the premises are suitable for release for unrestricted use."

As stated above, the NRC staff has determined that "all special nuclear material relating to this license has been properly disposed". Americium is a radioactive daughter product of Plutonium and was released via the termination of License SNM-1174.

The concentrations and sources of americium are discussed and described in the following NRC/ORAU/ORISE documents:

- ORAU Interim Confirmatory Survey Report (January 31, 1989).
- ORAU Final Confirmatory Survey Report (January, 1991).
- NRC Environmental Assessment and Finding of No Significant Impact (FONSI) (February 5, 1993).
- Federal Register, Volume 58, No. 28, pages 8432 through 8434 (February 12, 1993).

**NRC Comment:**

7. Were there any radioactive effluent discharges from the sanitary lagoons that could have affected surface/subsurface contamination in onsite or offsite areas?

**RESPONSE:**

The following information is contained in the 1994 Cimarron Radiological Characterization Report (Section 15.0, pages 15-2 through 15-4):

> "C. Characterization Data (Drain Line from Closed Sanitary Lagoons to Cimarron River):
>
> This four-inch steel drain line was used for liquid effluent discharges from the East and West Sanitary Lagoons to the Cimarron River during Cimarron Facility operations. The effluent was sampled prior to discharge to ensure that the effluent would meet Cimarron license limits. A weir box with a continuous sampler was used to collect a 24-hour sample which was analyzed daily.
>
> This drain line was excavated and removed in June, 1985. A gamma survey was conducted after this drain line was removed. The surveys were taken at the bottom, at the surface and at one meter above the surface of the excavated trench. These survey results are shown on Drawing No. 85POSTUR-0."

As discussed above, effluent discharges occurred at the Cimarron Facility in the Sanitary Lagoons which were in accordance with all license requirements and the associated regulatory guidance. In addition, the NRC received all information regarding the release of SNM in effluents from the Cimarron Facility. These reports were submitted to the NRC in accordance with 10 CFR 70.59 until the NRC letter dated September 14, 1990 allowed for the discontinuation of these reports.

In addition to the Phase II characterizations performed to date, Cimarron Corporation will also survey/sample the outfalls which lead to the Cimarron River as well as areas downstream from the outfalls to ensure that any potential releases from past operations have not contaminated surface/sub-surface areas either on-site or off-site. This additional characterization data will also be included in the Phase II Final Status Survey Report.

ATTACHMENT 1

# CIMARRON CORPORATION

## RESURVEY OF COAL BUILDING FLOOR

THE COAL BUILDING FLOOR WAS SURVEYED IN 1993. THERE WERE THREE AREAS IN THE COAL MAINTENANCE SHOP THAT INDICATED ELEVATED DIRECT READINGS. THE AREAS WERE LOCATED NEAR THE SOUTH EXIT DOOR AT THE BASE OF TWO I-BEAMS (1-SQUARE FOOT AREA AROUND ONE I-BEAM AND ONE 2-SQUARE FOOT AREA AROUND THE OTHER I-BEAM)AND A 3-SQUARE FOOT AREA EAST OF THE I-BEAMS. THE THREE AREAS WERE DECONTAMINATED (NEEDLE GUNNED) AND THEN RE-SURVEYED. ALL READINGS WERE WELL BELOW THE RELEASE LIMITS (5000 DPM/100CM$^2$) FOR BOTH ALPHA AND BETA. THESE THREE AREAS WERE RE-SURVEYED AGAIN ON JUNE 27, 1995 USING A LUDLUM MODEL 177 INSTRUMENT IN ORDER TO ENSURE THAT THESE AREAS WERE FREE OF CONTAMINATION. THE RESULTS OF THESE SURVEYS ARE LISTED BELOW.

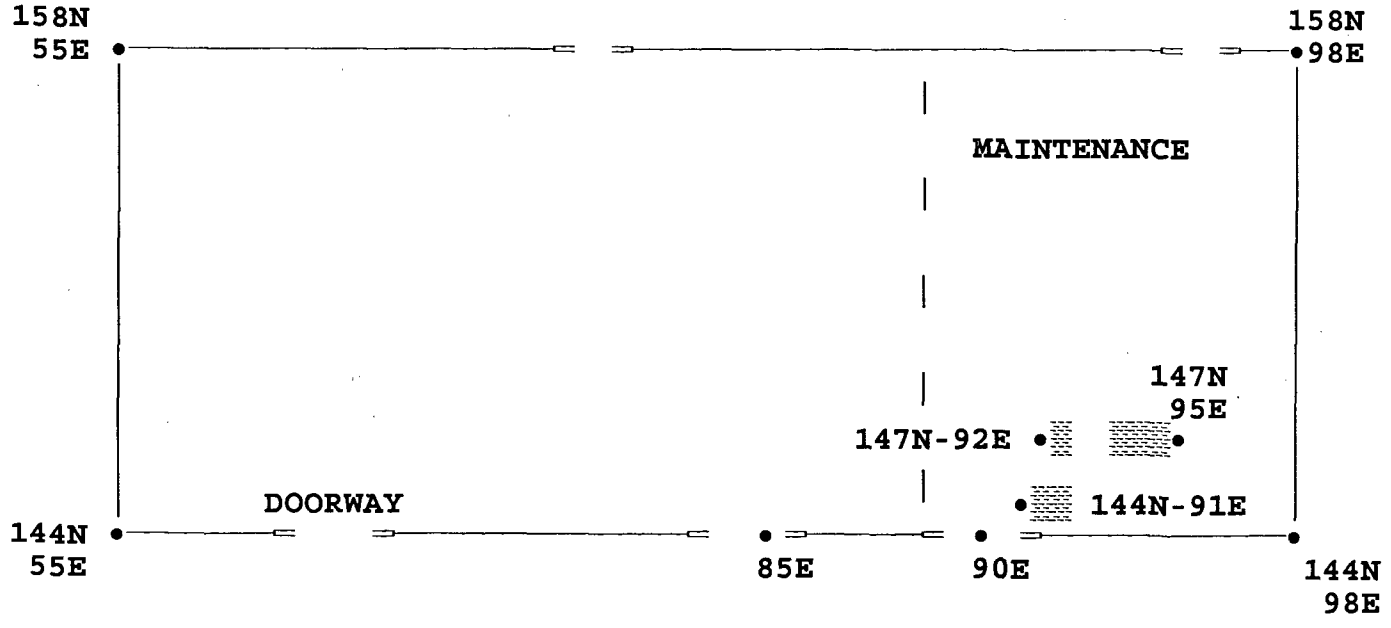
MAX. DIRECT ALPHA READING: 80 DPM/100CM$^2$ (6-27-95)

AVG. DIRECT ALPHA READING: 50 DPM/100CM$^2$ (6-27-95)

MAX. DIRECT BETA READING: 1430 DPM/100CM$^2$ (6-27-95)

AVG. DIRECT BETA READING: 760 DPM/100CM$^2$ (6-27-95)

LUDLUM MODEL 177 CI NO.:51 SERIAL NO.:114616 PROBE:43-89 CI NO.:144
ALPHA SOURCE: V-615 6665 DPM SOURCE CK.:581,550 BKG.:3 CP.5M MDA:94 DPM
BETA SOURCE: 9756 5870 DPM SOURCE CK.:601,583 BKG.:145 CP.5M MDA:658 DPM




SURVEY PERFORMED BY IRVING POWELL DATE: 6-27-95

ORISE 92/G-57

Prepared by
Oak Ridge Associated
Universities

Prepared for
U.S. Nuclear
Regulatory
Commission's
Region III Office

Sponsored by
Division of
Industrial and Medical
Nuclear Safety

# CONFIRMATORY RADIOLOGICAL SURVEY FORMER BURIAL GROUND CIMARRON CORPORATION FACILITY CRESCENT, OKLAHOMA

B. M. SMITH

Environmental Survey and Site Assessment Program
Energy/Environment Systems Division

FINAL REPORT
JULY 1992

# CONFIRMATORY RADIOLOGICAL SURVEY
# FORMER BURIAL GROUND
# CIMARRON CORPORATION FACILITY
# CRESCENT, OKLAHOMA

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Region III Office

**FINAL REPORT**

**JULY 1992**

This report is based on work performed under an Interagency Agreement (NRC Fin. No. A-9076) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Institute for Science and Education's Energy/Environment Systems Division performs complementary work under contract # DE-AC05-76OR00033 between the U.S. Department of Energy and Oak Ridge Associated Universities.

CONFIRMATORY RADIOLOGICAL SURVEY
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

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# CRESCENT, OKLAHOMA

## INTRODUCTION

The Kerr-McGee Corporation operated the Cimarron Facility in Crescent, Oklahoma to produce slightly enriched (approximately 3%) uranium fuel and mixed oxide (uranium plus plutonium) reactor fuel between 1965 and 1975. These activities were conducted under license SNM-928 with the Atomic Energy Commission, predecessor to the Nuclear Regulatory Commission (NRC). In 1983, Sequoyah Fuels Corporation (SFC) became the owner of the Cimarron Facility, when Kerr-McGee Nuclear Corporation was divided into SFC and Quivira Mining Corporation. Later, Cimarron Corporation, a subsidiary of the Kerr-McGee Nuclear Corporation, became responsible for the Cimarron Facility.

Decontamination of the Cimarron Facility began in 1979 with the goal of removing all contaminated equipment and materials so the facility could be released for unrestricted use. The decontamination and decommissioning project was divided into several phases, which involved the Mixed Oxide Plant, the Uranium Plant, the on-site Burial Ground, and the Sanitary Lagoons. Decontamination and decommissioning activities involving the Mixed Oxide Plant and the Sanitary Lagoons are nearing completion, and the Uranium Plant is in the process of being decontaminated.

Decontamination activities have been completed for the former Burial Ground. The Burial Ground was opened in March 1966 and used for the disposal of low level uranium wastes and thorium contaminated materials, transferred from another Kerr-McGee plant site; its use was discontinued in August 1970. Burial records indicate that 1,303 kg of depleted uranium, 148 kg of enriched uranium, and 5,555 kg of natural thorium were buried at this location. Excavation and removal of the buried waste and contaminated soil was initiated in 1986 and completed in 1988.

Initial decontamination activities for the former Burial Ground were completed by Cimarron Corporation in 1988. In August 1988, at the request of the NRC, Oak Ridge Associated Universities (ORAU) conducted a confirmatory survey of the former Burial Ground[1]. Survey activities consisted of gamma surface scans, exposure rate measurements, surface soil sampling, and subsurface soil and water sampling. Gamma scans identified 30 areas of elevated direct radiation. Clean-up of the areas was initiated immediately after their identification and follow-up surveys indicated that the clean-up was effective at all locations with the exception of Trench #1. At the time of the 1988 ORAU survey, contaminated soil meeting Option 2 (on-site burial) disposal concentration limits was stored at the south end of the Burial Ground, inside the fenced area. In April 1991, this material was moved to the yard beside the Uranium Plant. Additional decontamination was performed by Cimarron Corporation by excavation of approximately 14,000 cubic feet of soil, which was removed to the yard beside the Uranium Plant. No additional contaminated soil was identified by the final surveys[2] performed by Cimarron Corporation.

At the request of the NRC's Region III Office, the Environmental Survey and Site Assessment Program (ESSAP) of ORAU conducted a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility. The survey was performed to provide supporting information to confirm the radiological status of the site relative to the applicable NRC guidelines for release of the former Burial Ground for unrestricted use. This report summarizes the procedures and results of the survey.

## FACILITY DESCRIPTION

The Cimarron Corporation Facility is located on a site of approximately 450 hectares in Logan County, about 8 kilometers south of Crescent, Oklahoma (Figure 1). The site includes the Uranium Plant, the Mixed Oxide Plant, the former Burial Ground, two Sanitary Lagoons, and a Waste Evaporation Pond (Figure 2). The former Burial Ground occupies approximately

8,600 $m^2$ and is located at the northeast edge of the site. The former Burial Ground includes four trenches within a fenced area (Figure 3) which are approximately 3 meters deep and 1 to 2 meters wide.

## PROCEDURES

### OBJECTIVE

The objective of the independent survey was to provide supporting information to confirm that the results of the licensee's decontamination and decommissioning efforts were effective in meeting the NRC guidelines for unrestricted use. ESSAP also reviewed the supporting documentation, provided by the licensee, to evaluate the accuracy of the information and to assure that a complete description of the radiological status of the former Burial Ground was provided.

### DOCUMENT REVIEW

As part of the confirmatory activities, ESSAP reviewed the final survey report prepared by Cimarron Corporation for the Burial Ground[2]. Data and survey results presented in the final report were reviewed to assess the adequacy of the decontamination activities and to compare the licensee's survey results to the established release guidelines.

### SURVEY PROCEDURES

During the period of December 9 through 12, 1991, ESSAP performed a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility. The survey was performed in accordance with a plan developed by ESSAP dated November 25, 1991[3] and submitted to the NRC.

## Reference Grid

The 10 m reference grid utilized by the licensee was re-established by ESSAP for referencing measurements and sampling (Figure 3).

## Surface Scans

Surface scans of the Burial Ground were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters with audible indicators. Locations of elevated direct radiation were marked for further investigation (Figure 4).

## Exposure Rate Measurement

Exposure rate measurements were performed at 1 meter above the surface at all grid line intersections. Measurements were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters and cross-calibrated with a pressurized ionization chamber (PIC).

## Soil Sampling

Surface soil samples (depth 0-15 cm) were collected from grid line intersections, trench walls (approximately 1 meter above the trench floor), four piles of soil stored outside of the fenced area, locations of elevated activity identified by Cimarron Corporation and ORAU during previous surveys, and at locations of elevated direct radiation identified by the surface scans during this survey (Figures 5 and 6).

Subsurface soil samples were collected at approximately 15 to 60 cm intervals from 16 boreholes, which measured in depth from 0 to 170 cm. Borehole drilling sites were selected from locations of elevated activity identified by Cimarron Corporation and ORAU during previous surveys (Figure 7).

## SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and direct measurement data were returned to the ESSAP laboratory in Oak Ridge, TN for analyses and interpretation. Soil samples were analyzed by gamma spectrometry. Radionuclides of primary interest were U-235, U-238, and Th-232; however, spectra were also reviewed for other identifiable photopeaks. Selected soil samples were analyzed by alpha spectrometry for isotopic uranium.

Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B. Results of the independent measurements were compared to the NRC guidelines (Appendix C).

# FINDINGS AND RESULTS

## DOCUMENT REVIEW

The documentation provided by Cimarron Corporation was thorough and the radiological data provided in the final report demonstrated that the residual activity levels satisfied the established decommissioning guidelines.

## SURVEY RESULTS

### Surface Scans

Gamma scans of the former Burial Ground identified one area of slightly elevated direct radiation at 108N, 53E (Figure 4). This location was noted for further investigation.

## Exposure Rate Measurements

Exposure rate measurements are summarized in Table 1. Exposure rates for the Burial Ground ranged from 9 to 14 $\mu$R/h.

## Radionuclide Concentrations in Soil Samples

Twelve samples were analyzed by alpha spectrometry for isotopic uranium. The uranium concentrations for these samples are summarized in Table 2 and indicate slight enrichment above natural isotopic abundances for U-234 and U-235. Isotopic uranium concentrations ranged from 0.5 to 66.2 pCi/g for U-234, from 0.1 to 3.2 pCi/g for U-235, and from 0.4 to 26.2 pCi/g for U-238. The concentrations of total uranium ranged from 0.9 to 95.6 pCi/g. On the basis of alpha spectrometry analysis, the ratio of U-234 to U-235 is approximately 20:1. This ratio was used to calculate the total uranium concentrations in soil samples analyzed by gamma spectrometry.

Concentrations of radionuclides in surface soil samples are summarized in Table 1. Concentration ranged from 0.1 to 1.6 pCi/g for U-235 and from $<1.2$ to 10.8 pCi/g for U-238. The concentrations of total uranium in the surface soil samples ranged from $<3.1$ to 44 pCi/g. The highest concentration was identified at 69N, 62E, which was an area of elevated direct radiation identified during the previous survey.

Thorium concentrations determined for the surface soil samples are summarized in Table 1. Gamma spectra were reviewed and the thorium-232 series radionuclides were in equilibrium. Total thorium (Th-232 + Th-228) concentrations ranged from 0.4 to 5.5 pCi/g. The highest concentration was identified at 30N, 50E.

Uranium and thorium concentrations in subsurface soil samples are summarized in Table 3. Uranium concentrations ranged from 0.1 to 1.2 pCi/g for U-235, from $<1.3$ to 10.8 pCi/g for U-238, and from $<5.5$ to 33 pCi/g for total uranium. The highest concentration was identified

at 95N, 50E in the sample taken at a depth of 0-15 cm. Uranium concentrations for samples collected from the boreholes at 70N, 57E; 73N, 66E; 90N, 65E, and 95N, 45E increased with depth. The total thorium concentrations ranged from $<1.5$ to 4.9 pCi/g.

## COMPARISON OF RESULTS WITH GUIDELINES

Background exposure rates were determined during the 1988 ORAU survey (Table 4) and averaged 10 $\mu$R/h. Surface scans identified one area of slightly elevated direct radiation at 108N, 53E. This area had a gamma exposure rate of 14 $\mu$R/h. Therefore, this area does not exceed the guideline of 10 $\mu$R/h above background, as specified in Appendix C, or the 5 $\mu$R/h above background guideline, currently in use by the NRC[4].

The guidelines for residual concentrations of thorium and uranium wastes in soil are presented in Appendix C. The primary contaminants of concern for this site are enriched uranium, depleted uranium and natural thorium. Applicable soil concentration guidelines are:

| | |
|---|---|
| Enriched Uranium | 30 pCi/g |
| Depleted Uranium | 35 pCi/g |
| Natural Thorium* | 10 pCi/g |

*With all daughters present and in equilibrium.

Since the residual activity may be a combination of enriched and depleted uranium, and the alpha spectrometry analyses indicate that the uranium is slightly enriched in U-234 and U-235, the more conservative guideline value of 30 pCi/g was used for comparison with the uranium results.

These guidelines are expressed in terms of concentrations above normal background levels. Background radionuclide concentrations in soil were determined during the 1988 ORAU survey (Table 4). Total uranium concentrations ranged from $<1.2$ to 2.0 pCi/g (1.6 pCi/g average)

and total thorium concentrations ranged from 0.9 to 2.1 pCi/g (1.4 pCi/g average). Therefore, the sample analysis results indicating that the NRC guidelines have been exceeded are 31.6 pCi/g for total uranium and 11.4 pCi/g for total thorium.

Gamma spectrometry analysis identified 2 surface soil samples with total uranium concentrations which exceeded the guideline value. These samples included the soil samples collected from the previously identified area of elevated activity at 69N, 62E (44 pCi/g), and from the borehole located at 95N, 50E (33 pCi/g, sample depth 0-15 cm). Alpha spectrometry analysis identified 3 surface soil samples which exceeded the guideline value for uranium. These samples included the soil samples collected from a previously identified area of elevated direct radiation at 91N, 42E (33.2 pCi/g), the area of elevated direct radiation identified by this survey at 108N, 53E (95.6 pCi/g) and the borehole at 25N, 70E (43.6 pCi/g, sample depth 0-15 cm).

Total thorium concentrations in all surface and subsurface soil samples were less than the 10 pCi/g above background guideline value.

## SUMMARY

At the request of the Nuclear Regulatory Commission Region III Office, the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities conducted a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility during December 9 through 12, 1991. The survey included surface scans, exposure rate measurements, and the determination of radionuclide concentrations in soil samples.

Surface scans identified one area of slightly elevated direct radiation; however, the exposure rate measurement was within the guideline value.

Total thorium concentrations in all samples were below the concentration guideline. Total uranium concentrations in all samples, except five, were below the uranium concentration guideline. Five surface soil samples exceeded the concentration guideline; these samples were

collected from 69N, 62E; 95N, 50E; 91N, 42E; 108N, 53E and 25N, 70E and total uranium concentrations were 44 pCi/g, 33 pCi/g, 33.2 pCi/g, 95.6 pCi/g, and 43.6 pCi/g respectively.

The results of the confirmatory radiological survey indicate that all samples, with 5 exceptions, were below the concentration guidelines for total uranium and total thorium. The locations which exceed the uranium concentration guideline are scattered over the former Burial Ground Area.

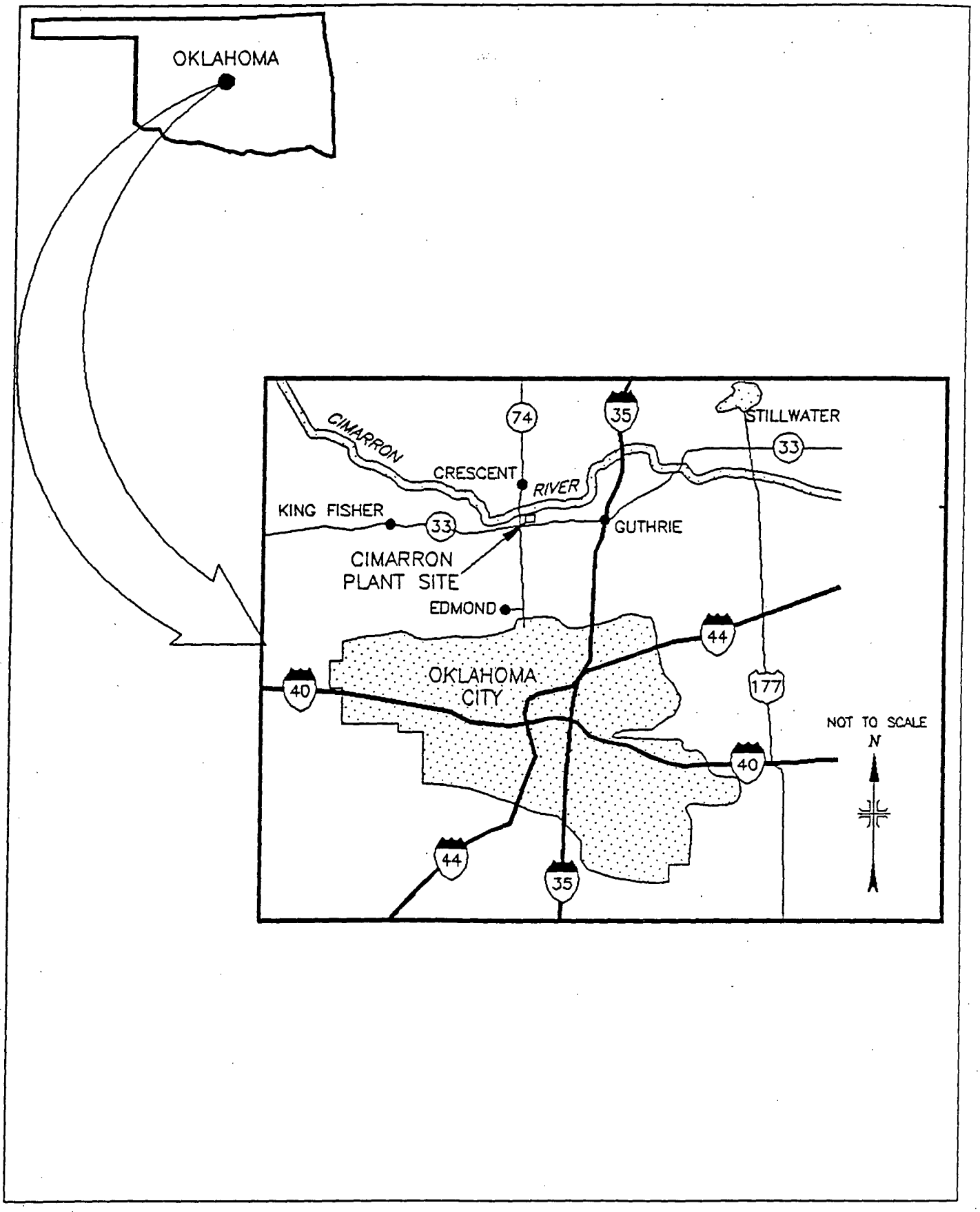



FIGURE 1: Location of the Cimarron Facility, Crescent, Oklahoma

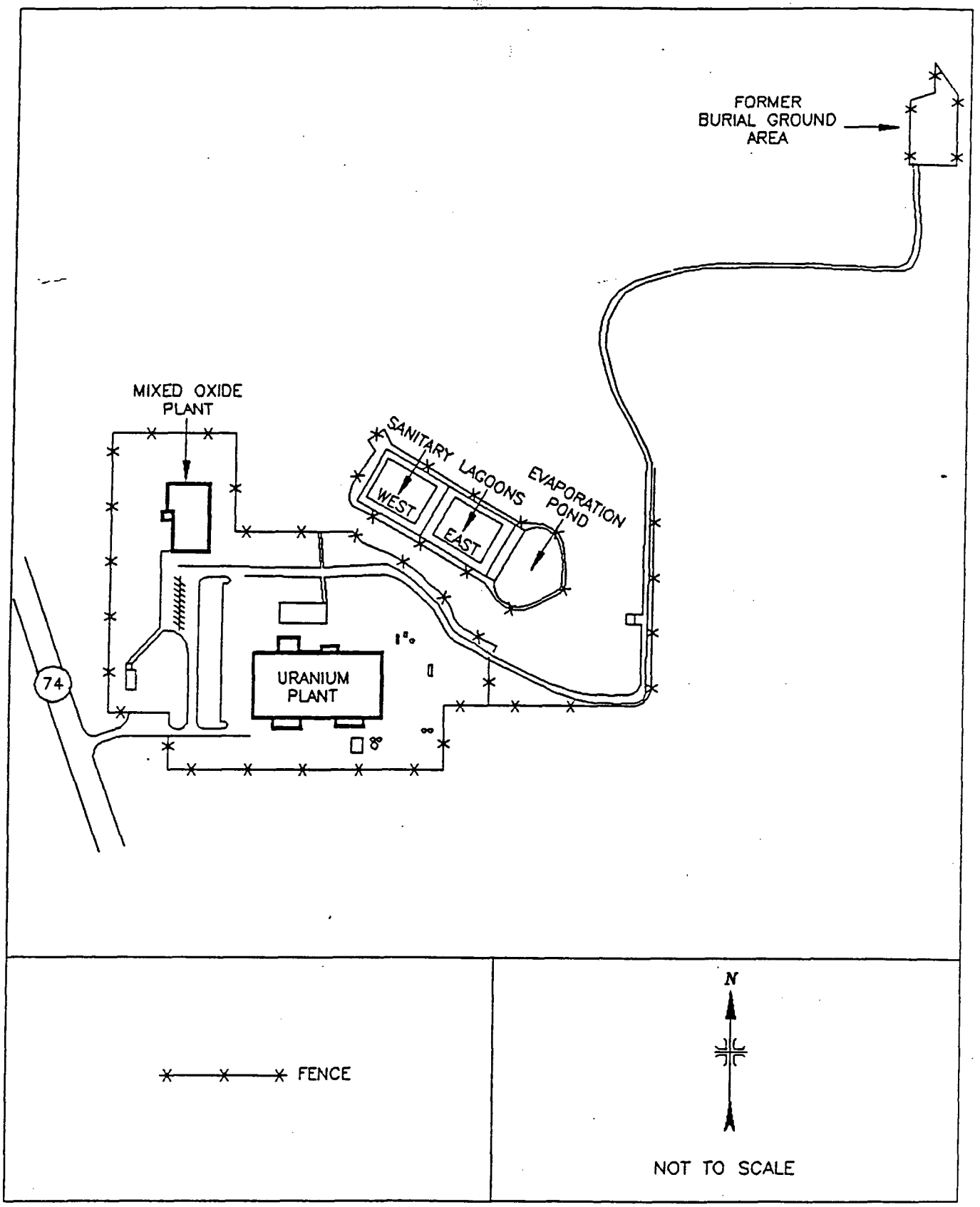



FIGURE 2: Plot Plan – Cimarron Facility

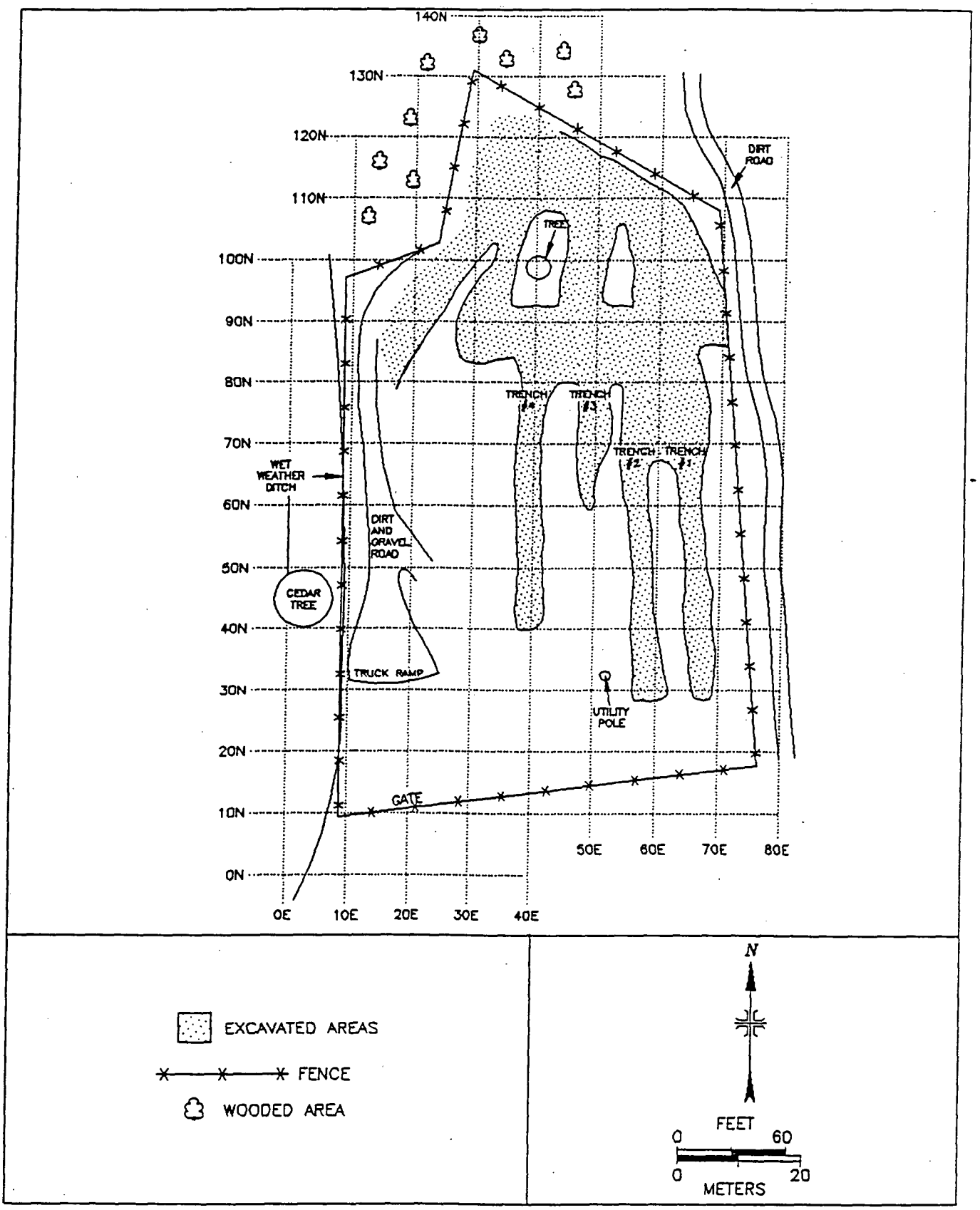



FIGURE 3: Former Burial Ground Area

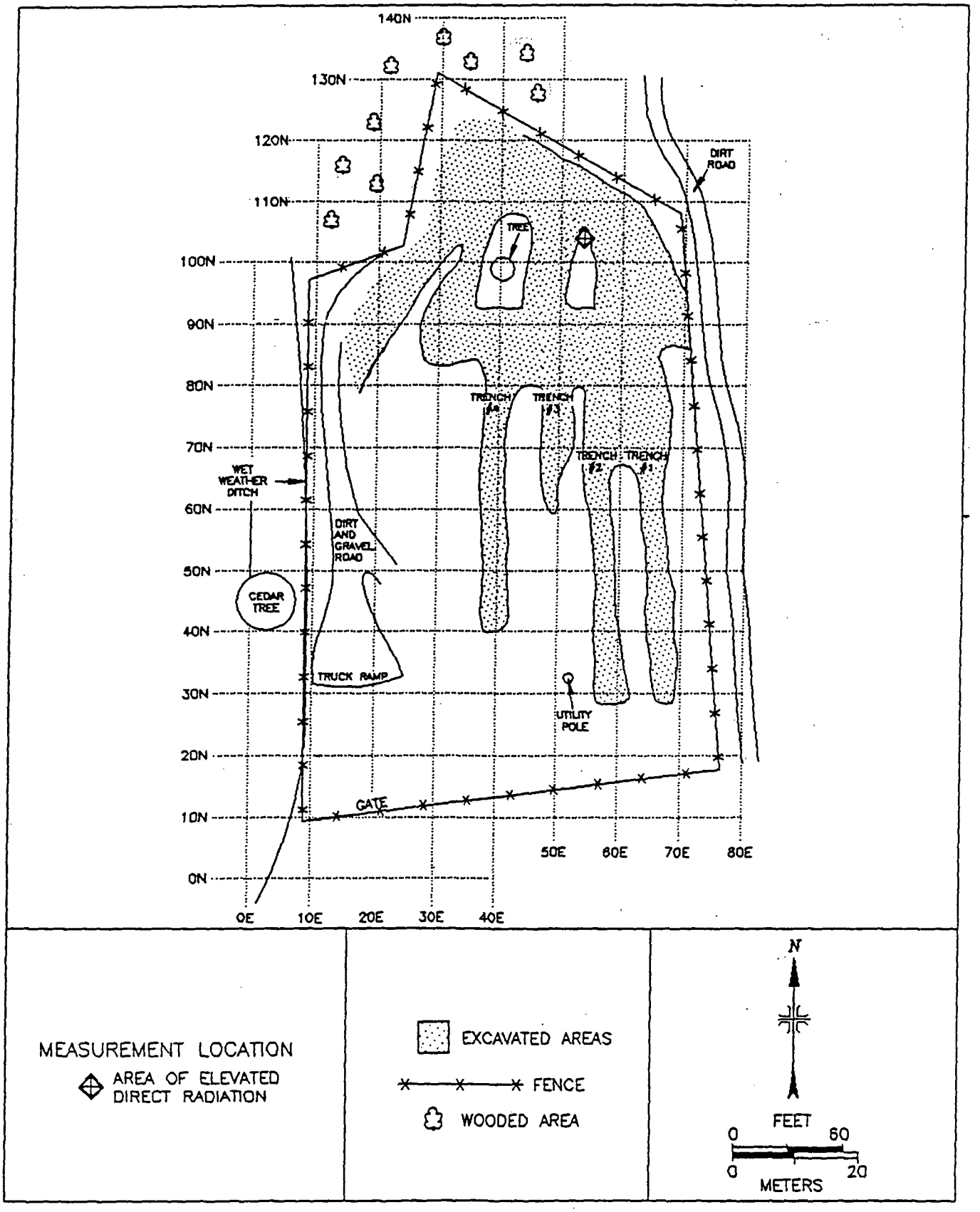



FIGURE 4: Former Burial Ground Area – Elevated Direct Radiation Location

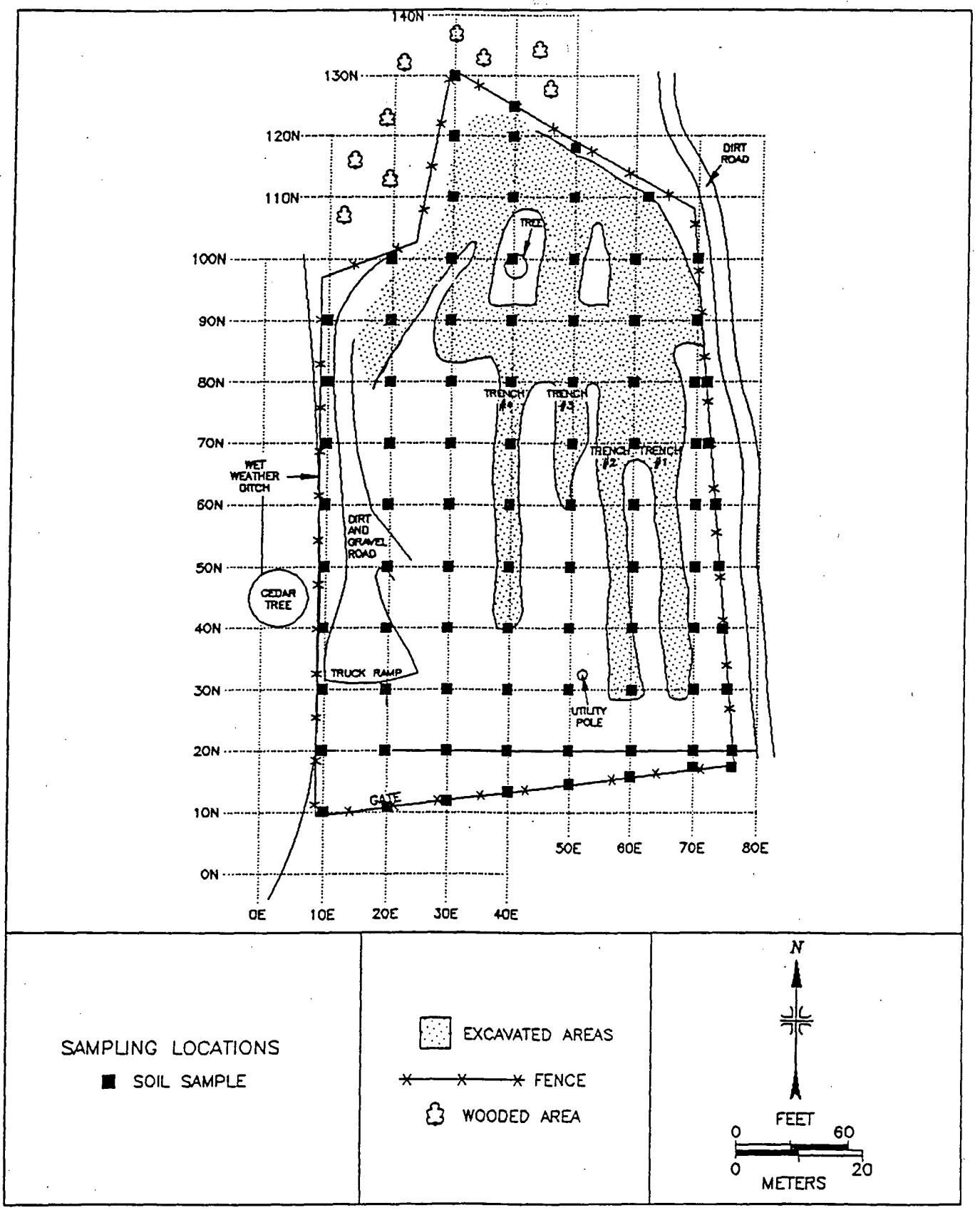



FIGURE 5: Former Burial Ground Area – Surface Soil Sampling Locations at Grid Line Intersections

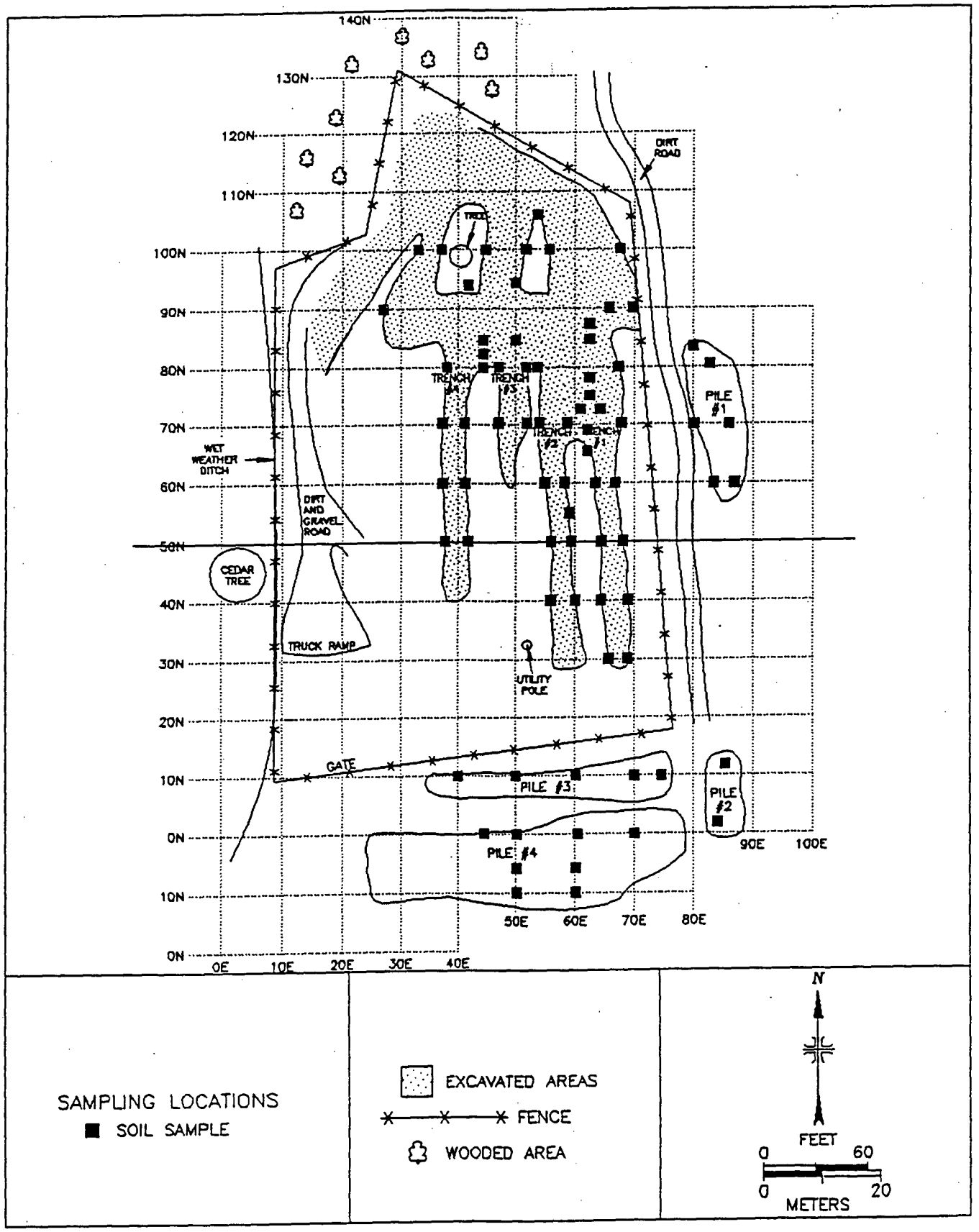



FIGURE 6: Former Burial Ground Area – Surface Soil Sampling Locations from Trench Excavations and Soil Piles

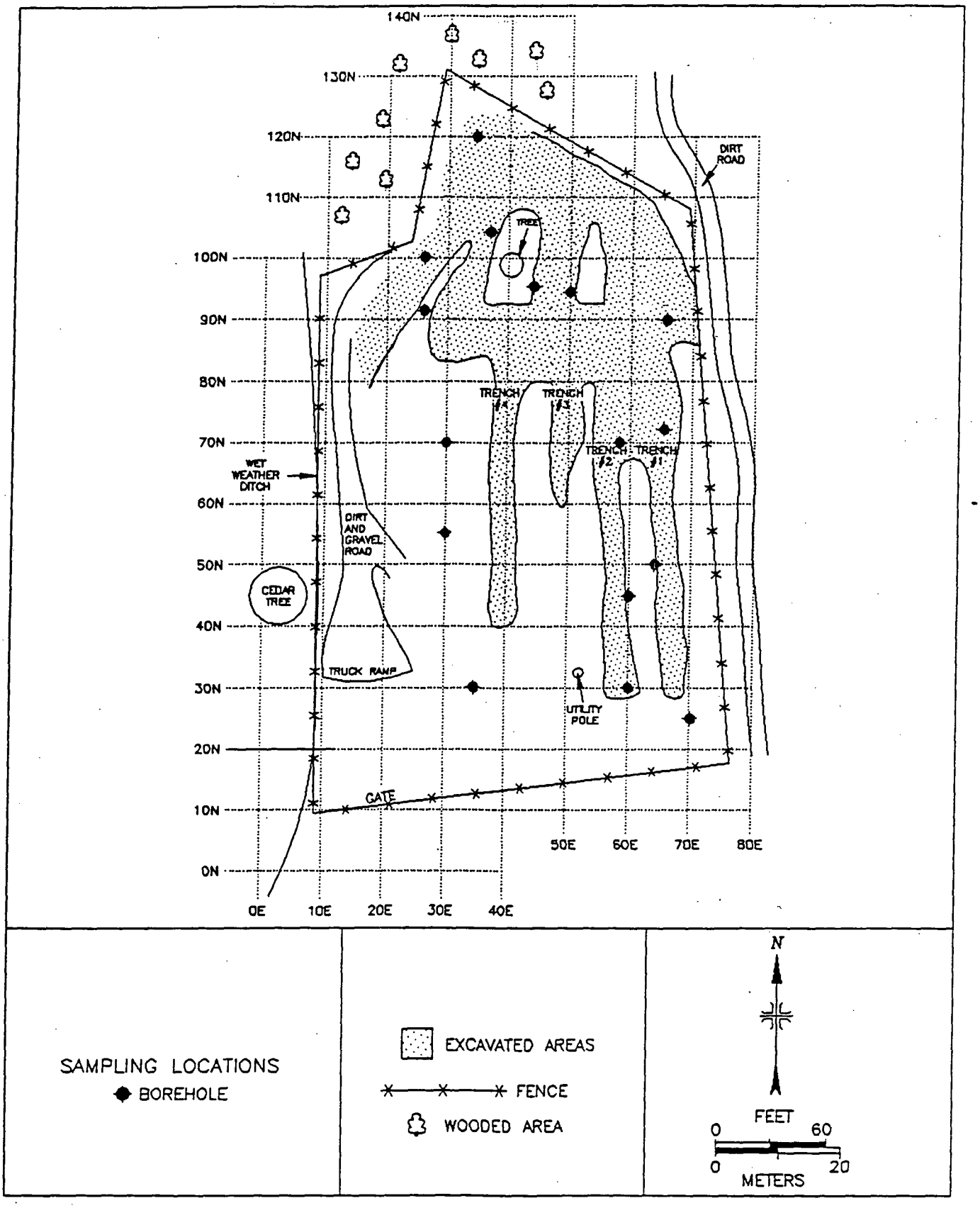



FIGURE 7: Former Burial Ground Area – Subsurface Soil Sampling Locations

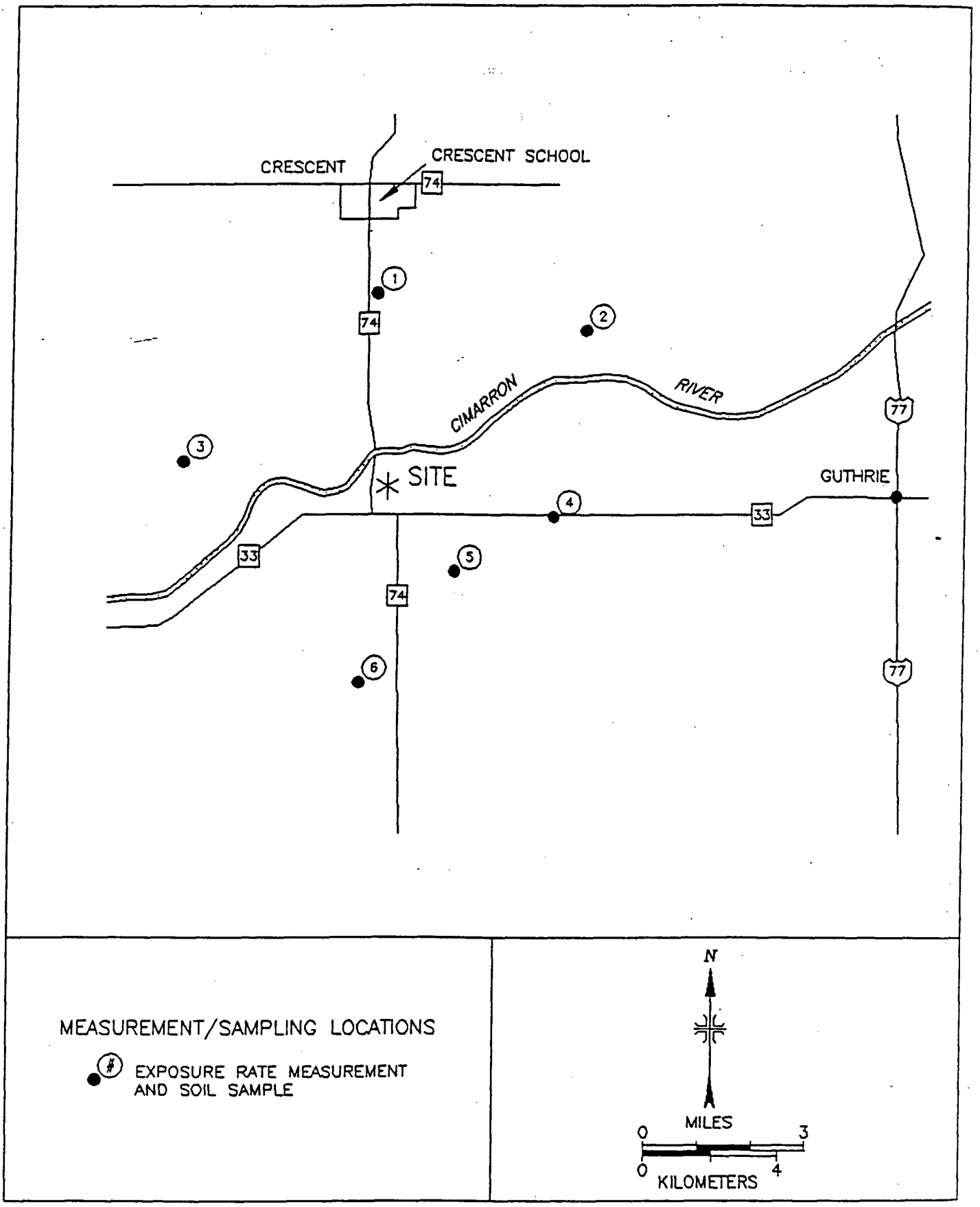



FIGURE 8: Background Measurement and Sampling Locations

TABLE 1

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| **Grid Line Intersections** | | | | | |
| 10N, 10E | 10 | 0.2 ± 0.4[e] | 1.8 ± 1.5 | 6.0 | 1.7 |
| 11N, 20E | 10 | 0.3 ± 0.1 | 1.5 ± 0.6 | 7.8 | 1.4 |
| 12N, 30E | 10 | 0.3 ± 0.3 | 0.9 ± 1.2 | 7.2 | 1.3 |
| 14N, 40E | 10 | 0.1 ± 0.1 | 3.4 ± 1.9 | 5.5 | 2.1 |
| 15N, 50E | 10 | 0.2 ± 0.1 | 1.6 ± 0.8 | 5.8 | 1.9 |
| 15N, 60E | 9 | 0.3 ± 0.1 | 4.2 ± 1.8 | 11 | 2.5 |
| 17N, 70E | 10 | 0.7 ± 0.6 | 9.1 ± 2.3 | 24 | 1.6 |
| 17N, 75E | 9 | ---[f] | --- | --- | 2.6 |
| 20N, 10E | 10 | 0.2 ± 0.1 | 1.7 ± 0.7 | 5.9 | 2.2 |
| 20N, 20E | 9 | 0.3 ± 0.1 | 2.8 ± 1.3 | 9.1 | 0.7 |
| 20N, 30E | 10 | 0.1 ± 0.1 | 1.3 ± 0.8 | 3.4 | 0.4 |
| 20N, 40E | 10 | 0.2 ± 0.1 | 1.1 ± 0.9 | 7.3 | 2.0 |
| 20N, 50E | 10 | 0.2 ± 0.1 | 3.2 ± 1.1 | 7.4 | 1.5 |
| 20N, 60E | 10 | 0.1 ± 0.1 | 1.4 ± 0.8 | 3.5 | 1.7 |
| 20N, 70E | 10 | 0.2 ± 0.1 | 2.5 ± 0.9 | 6.7 | 1.6 |
| 20N, 75E | 10 | --- | --- | --- | 2.2 |
| 30N, 10E | 10 | 0.3 ± 0.1 | <1.5 | <7.8 | 1.9 |
| 30N, 20E | 9 | 0.4 ± 0.3 | 3.1 ± 0.9 | 11 | 1.5 |
| 30N, 30E | 10 | 0.2 ± 0.1 | 2.8 ± 1.6 | 7.0 | 2.2 |
| 30N, 40E | 10 | 0.2 ± 0.1 | 1.9 ± 1.1 | 6.1 | 1.9 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate (μR/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 30N, 50E | 10 | 0.4 ± 0.5 | 7.4 ± 1.4 | 16 | 5.5 |
| 30N, 60E | 10 | 0.3 ± 0.1 | 1.9 ± 0.8 | 8.2 | 1.9 |
| 30N, 70E | 10 | 0.3 ± 0.1 | 3.6 ± 0.8 | 9.9 | 1.4 |
| 30N, 74E | 9 | 0.3 ± 0.1 | 2.9 ± 0.9 | 9.2 | 1.5 |
| 40N, 10E | 9 | 0.2 ± 0.1 | 1.7 ± 0.6 | 5.9 | 1.6 |
| 40N, 20E | 9 | 0.3 ± 0.1 | 3.4 ± 0.9 | 9.7 | 1.6 |
| 40N, 30E | 10 | 0.1 ± 0.2 | 1.5 ± 0.6 | 3.6 | 1.4 |
| 40N, 40E | 10 | 0.5 ± 0.3 | 2.0 ± 0.7 | 13 | 2.0 |
| 40N, 50E | 11 | 0.1 ± 0.1 | 1.3 ± 1.2 | 3.4 | 1.7 |
| 40N, 60E | 10 | 0.1 ± 0.1 | <2.0 | <4.1 | 1.8 |
| 40N, 70E | 9 | 0.1 ± 0.2 | 0.6 ± 0.8 | 2.7 | 1.1 |
| 40N, 74E | 9 | 0.3 ± 0.3 | 3.7 ± 1.2 | 10 | 2.3 |
| 50N, 10E | 10 | 0.1 ± 0.1 | 1.4 ± 1.4 | 3.5 | 1.5 |
| 50N, 20E | 9 | 0.2 ± 0.1 | 2.0 ± 0.8 | 6.2 | 1.9 |
| 50N, 30E | 10 | 0.2 ± 0.1 | 2.4 ± 1.3 | 6.6 | 1.8 |
| 50N, 40E | 10 | 0.1 ± 0.1 | 3.5 ± 1.7 | 5.6 | 2.3 |
| 50N, 50E | 11 | 0.3 ± 0.1 | 2.1 ± 1.0 | 8.4 | 2.8 |
| 50N, 60E | 10 | 0.2 ± 0.1 | 1.4 ± 0.5 | 5.6 | 2.0 |
| 50N, 70E | 10 | 0.3 ± 0.1 | 2.1 ± 1.0 | 8.4 | 2.3 |
| 50N, 73E | 9 | 0.2 ± 0.1 | 1.4 ± 1.3 | 5.6 | 1.8 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 60N, 10E | 10 | 0.2 ± 0.1 | 2.2 ± 0.8 | 6.4 | 1.5 |
| 60N, 20E | 10 | 0.1 ± 0.1 | 1.4 ± 0.9 | 3.5 | 2.1 |
| 60N, 30E | 10 | 0.4 ± 0.5 | 4.2 ± 2.1 | 13 | 2.3 |
| 60N, 40E | 10 | 0.2 ± 0.1 | <1.2 | <5.4 | 1.6 |
| 60N, 50E | 11 | 0.3 ± 0.1 | 1.4 ± 1.1 | 7.7 | 2.0 |
| 60N, 60E | 10 | 0.4 ± 0.1 | 2.9 ± 1.5 | 11 | 2.5 |
| 60N, 70E | 9 | 0.2 ± 0.1 | 2.0 ± 1.2 | 6.2 | 1.9 |
| 60N, 72E | 10 | 0.2 ± 0.3 | 1.9 ± 1.1 | 6.1 | 2.0 |
| 70N, 10E | 10 | 0.1 ± 0.1 | 1.2 ± 1.0 | 3.3 | 1.9 |
| 70N, 20E | 10 | 0.2 ± 0.1 | 1.2 ± 1.0 | 5.4 | 1.8 |
| 70N, 30E | 10 | 0.9 ± 0.6 | 7.9 ± 1.6 | 27 | 2.3 |
| 70N, 40E | 11 | 0.9 ± 0.5 | 10.8 ± 2.3 | 30 | 2.3 |
| 70N, 50E | 11 | 0.3 ± 0.1 | 3.0 ± 1.1 | 9.3 | 1.7 |
| 70N, 60E | 11 | 0.8 ± 0.4 | 6.3 ± 1.0 | 23 | 1.9 |
| 70N, 70E | 10 | 0.2 ± 0.1 | 2.1 ± 0.8 | 3 | 2.1 |
| 70N, 72E | 10 | 0.4 ± 0.5 | 5.6 ± 1.7 | 14 | 2.9 |
| 80N, 10E | 10 | 0.3 ± 0.2 | <1.4 | <7.7 | 1.6 |
| 80N, 20E | 11 | 0.2 ± 0.1 | 2.4 ± 1.7 | 6.6 | 2.1 |
| 80N, 30E | 11 | 0.2 ± 0.1 | 2.2 ± 1.1 | 6.4 | 2.0 |
| 80N, 40E | 10 | 0.2 ± 0.1 | 1.6 ± 0.9 | 5.8 | 2.1 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 80N, 50E | 11 | 0.9 ± 0.5 | 3.1 ± 0.9 | 22 | 1.9 |
| 80N, 60E | 10 | --- | --- | --- | 1.7 |
| 80N, 70E | 10 | 0.3 ± 0.1 | 2.3 ± 1.6 | 8.6 | 2.5 |
| 80N, 71E | 9 | 0.3 ± 0.4 | 2.8 ± 1.0 | 9.1 | 2.4 |
| 90N, 10E | 10 | 0.2 ± 0.1 | 1.7 ± 1.4 | 5.9 | 1.7 |
| 90N, 20E | 10 | 0.2 ± 0.1 | 2.1 ± 0.7 | 6.3 | 1.7 |
| 90N, 30E | 10 | 0.5 ± 0.3 | 5.6 ± 2.0 | 16 | 2.2 |
| 90N, 40E | 10 | 0.2 ± 0.1 | 1.1 ± 0.9 | 5.3 | 2.2 |
| 90N, 50E | 10 | 0.6 ± 0.4 | 3.7 ± 1.4 | 16 | 1.2 |
| 90N, 60E | 10 | 0.3 ± 0.3 | 6.5 ± 1.1 | 13 | 1.5 |
| 90N, 70E | 10 | 0.2 ± 0.1 | 3.1 ± 1.5 | 7.3 | 1.9 |
| 98N, 10E | 10 | 0.5 ± 0.3 | 1.7 ± 0.9 | 12 | 1.6 |
| 100N, 20E | 11 | 0.1 ± 0.1 | 2.0 ± 1.3 | 4.1 | 1.7 |
| 100N, 30E | 11 | 0.6 ± 0.3 | 5.8 ± 1.2 | 18 | 2.1 |
| 100N, 40E | 10 | 0.2 ± 0.1 | 1.9 ± 1.2 | 6.1 | <1.4 |
| 100N, 50E | 12 | 0.5 ± 0.3 | 5.2 ± 1.0 | 16 | 1.8 |
| 100N, 60E | 10 | 0.6 ± 0.1 | 6.1 ± 1.0 | 19 | 1.8 |
| 100N, 69E | 10 | 0.3 ± 0.1 | 2.3 ± 0.8 | 8.6 | 1.8 |
| 110N, 30E | 11 | 0.6 ± 0.4 | 4.2 ± 0.7 | 17 | 2.2 |
| 110N, 40E | 11 | 0.5 ± 0.4 | 5.6 ± 1.0 | 16 | 2.2 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 110N, 50E | 11 | 0.7 ± 0.4 | 6.1 ± 2.0 | 21 | 1.9 |
| 110N, 62E | 11 | 0.2 ± 0.1 | 1.6 ± 1.0 | 5.8 | 1.4 |
| 117N, 50E | 10 | 0.5 ± 0.4 | 2.7 ± 1.1 | 13 | 2.1 |
| 120N, 30E | 11 | 0.8 ± 0.4 | 5.0 ± 1.4 | 22 | 2.6 |
| 120N, 40E | 10 | 0.3 ± 0.1 | 4.8 ± 2.0 | 11 | 1.5 |
| 124N, 40E | 10 | 0.1 ± 0.1 | <1.5 | <3.6 | 2.1 |
| 130N, 30E | 10 | 0.3 ± 0.4 | 2.7 ± 1.0 | 9.0 | 1.6 |
| Trench #1 | | | | | |
| 30N, E Wall | 10 | 0.1 ± 0.1 | <1.9 | <4.0 | 1.5 |
| 30N, W Wall | 10 | 0.3 ± 0.1 | <1.9 | <8.2 | 1.9 |
| 40N, E Wall | 10 | 0.2 ± 0.1 | 1.4 ± 1.1 | 5.6 | 1.7 |
| 40N, W Wall | 10 | 0.2 ± 0.1 | <1.1 | <5.3 | <1.7 |
| 50N, E Wall | 10 | 0.1 ± 0.1 | <1.6 | <3.7 | 1.6 |
| 50N, W Wall | 10 | <0.4 | <1.7 | <10 | 1.4 |
| 60N, E Wall | 11 | 0.1 ± 0.1 | <1.0 | <3.1 | <1.0 |
| 60N, W Wall | 10 | 0.2 ± 0.1 | <1.3 | <5.5 | 1.9 |
| 70N, E Wall | 10 | 0.2 ± 0.1 | 1.7 ± 1.3 | 5.9 | 1.7 |
| 80N, E Wall | 10 | 0.1 ± 0.1 | <1.2 | <3.3 | 2.0 |
| 100N, E Wall | 10 | 0.3 ± 0.1 | 3.1 ± 1.8 | 9.4 | 2.2 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| **Trench #2** | | | | | |
| 40N, E Wall | 10 | 0.2 ± 0.1 | 1.2 ± 0.7 | 5.4 | 1.4 |
| 40N, W Wall | 10 | <0.5 | <2.0 | <13 | 2.1 |
| 50N, E Wall | 10 | 0.9 ± 0.1 | 3.9 ± 1.5 | 23 | 1.4 |
| 50N, W Wall | 10 | <0.5 | <1.8 | <12 | <1.5 |
| 60N, E Wall | 11 | 0.1 ± 0.1 | <1.2 | <3.3 | 1.8 |
| 60N, W Wall | 11 | <0.4 | <1.9 | <10 | 1.6 |
| 70N, W Wall | 11 | 0.4 ± 0.1 | 3.8 ± 1.6 | 12 | 1.5 |
| 80N, W Wall | 10 | 0.3 ± 0.1 | 1.5 ± 0.9 | 7.8 | 1.5 |
| 100N, W Wall | 10 | 0.3 ± 0.1 | <2.1 | <8.4 | 2.0 |
| **Trench #3** | | | | | |
| 70N, E Wall | 10 | 0.2 ± 0.1 | <1.2 | <5.4 | 1.9 |
| 70N, W Wall | 11 | <0.5 | 2.5 ± 1.2 | 13 | 1.9 |
| 80N, E Wall | 11 | --- | --- | --- | <1.3 |
| 80N, W Wall | 11 | 0.2 ± 0.1 | 1.8 ± 0.7 | 6.0 | 2.3 |
| 100N, E Wall | 11 | 0.1 ± 0.1 | <1.8 | <3.9 | 2.0 |
| 100N, W Wall | 11 | 0.1 ± 0.1 | <1.2 | <3.3 | 1.5 |
| **Trench #4** | | | | | |
| 50N, E Wall | 10 | 0.1 ± 0.1 | <1.9 | <4.0 | <1.7 |
| 50N, W Wall | 11 | 0.3 ± 0.1 | <1.2 | <7.5 | <1.7 |
| 60N, E Wall | 10 | 0.2 ± 0.1 | 2.6 ± 1.3 | 6.8 | 2.2 |
| 60N, W Wall | 10 | 0.2 ± 0.1 | <1.3 | <5.5 | 1.8 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 70N, E Wall | 11 | <0.5 | <1.9 | <12 | 2.1 |
| 70N, W Wall | 11 | 0.2 ± 0.1 | <1.3 | <5.5 | 1.6 |
| 80N, E Wall | 10 | <0.5 | <1.9 | <12 | 1.8 |
| 80N, W Wall | 10 | 0.2 ± 0.1 | 1.9 ± 1.0 | 6.1 | 1.3 |
| 90N, W Wall | 10 | 0.2 ± 0.1 | 2.9 ± 0.9 | 7.1 | <1.4 |
| 0N, E Wall | 10 | 0.4 ± 0.2 | 3.8 ± 1.7 | 12 | 2.1 |
| 100N, W Wall | 10 | 0.5 ± 0.1 | 3.8 ± 0.9 | 14 | 2.2 |
| **Pile #1** | | | | | |
| 60N, 82E | 10 | 0.3 ± 0.1 | 4.7 ± 1.4 | 11 | 1.3 |
| 60N, 85E | 10 | 0.3 ± 0.1 | 3.4 ± 0.9 | 9.7 | 1.4 |
| 70N, 80E | 10 | 0.5 ± 0.3 | 5.0 ± 1.3 | 16 | 1.8 |
| 70N, 85E | 10 | 0.2 ± 0.1 | 2.1 ± 0.8 | 6.3 | 2.3 |
| 80N, 83E | 10 | 0.4 ± 0.4 | 4.5 ± 1.8 | 13 | 1.6 |
| 82N, 80E | 10 | --- | --- | --- | 1.2 |
| **Pile #2** | | | | | |
| 3N, 85E | 11 | 0.2 ± 0.2 | 2.2 ± 0.9 | 6.4 | 2.0 |
| 11N, 85E | 10 | 0.1 ± 0.1 | 1.1 ± 0.6 | 3.2 | 1.7 |
| **Pile #3** | | | | | |
| 10N, 40E | 10 | 0.2 ± 0.1 | 1.2 ± 1.0 | 5.4 | 1.8 |
| 10N, 50E | 10 | 0.1 ± 0.1 | 1.7 ± 0.7 | 3.8 | 1.7 |
| 10N, 60E | 10 | 0.2 ± 0.1 | 1.8 ± 1.6 | 6.0 | 1.4 |
| 10N, 70E | 10 | 0.2 ± 0.1 | 2.3 ± 0.7 | 6.5 | 1.6 |
| 10N, 75E | 10 | 0.2 ± 0.1 | 2.0 ± 1.3 | 6.2 | 1.7 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| **Pile #4** | | | | | |
| 0, 45E | 10 | 0.4 ± 0.2 | 5.1 ± 1.0 | 14 | 2.5 |
| 0, 50E | 10 | 0.3 ± 0.3 | 7.8 ± 1.8 | 14 | 1.6 |
| 0, 60E | 10 | 0.2 ± 0.1 | 2.0 ± 0.6 | 6.2 | 1.6 |
| 0, 70E | 10 | 0.2 ± 0.1 | 1.1 ± 0.7 | 5.3 | 1.7 |
| 5S, 50E | 10 | 0.3 ± 0.2 | 3.3 ± 0.9 | 9.6 | 2.3 |
| 5S, 60E | 10 | 0.2 ± 0.1 | 2.0 ± 1.5 | 6.2 | 1.7 |
| 10S, 50E | 10 | 0.6 ± 0.4 | 6.6 ± 2.0 | 19 | 2.7 |
| 10S, 60E | 10 | 0.6 ± 0.3 | 9.2 ± 0.8 | 22 | 2.8 |
| **Previously Identified Areas of Elevated Activity** | | | | | |
| 57N, 64E | 10 | 0.3 ± 0.1 | 3.0 ± 1.7 | 9.3 | 2.8 |
| 65N, 62E | 11 | 0.2 ± 0.1 | 1.6 ± 1.4 | 5.8 | 3.6 |
| 69N, 62E | 11 | 1.6 ± 0.5 | 9.9 ± 2.2 | 44 | 1.4 |
| 70N, 59E | 11 | --- | --- | --- | 2.2 |
| 71N, 61E | 11 | 0.7 ± 0.3 | 7.0 ± 1.4 | 22 | 2.0 |
| 71N, 65E | 11 | 0.2 ± 0.1 | 2.7 ± 0.8 | 6.9 | 3.0 |
| 75N, 63E | 10 | 0.3 ± 0.1 | 3.5 ± 1.4 | 9.8 | 2.0 |
| 77N, 63E | 10 | 0.4 ± 0.3 | 3.8 ± 1.0 | 12 | 2.0 |
| 78N, 63E | 10 | 0.2 ± 0.3 | 3.9 ± 1.8 | 8.1 | 2.8 |

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above surface | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 83N, 45E | 10 | 0.2 ± 0.1 | 1.7 ± 0.8 | 5.9 | 1.5 |
| 84N, 65E | 10 | 0.5 ± 0.1 | 4.3 ± 1.3 | 15 | 2.3 |
| 85N, 45E | 10 | 0.2 ± 0.1 | 2.4 ± 0.8 | 6.6 | 1.7 |
| 85N, 50E | 10 | 0.5 ± 0.4 | 5.7 ± 1.8 | 16 | 1.4 |
| 87N, 65E | 10 | 0.3 ± 0.4 | 5.4 ± 1.6 | 12 | 1.8 |
| 90N, 66E | 10 | 0.3 ± 0.3 | 5.3 ± 1.0 | 12 | 1.9 |
| 90N, 68E | 9 | 0.3 ± 0.3 | 1.8 ± 1.0 | 8.1 | 1.0 |
| 91N, 42E | 10 | --- | --- | --- | 1.8 |
| 95N, 50E | 11 | 0.2 ± 0.1 | 3.4 ± 1.7 | 7.6 | 1.7 |
| **Area of Elevated Direct Radiation** 108N, 53E | 14 | --- | --- | --- | 4.2 |

[a]Refer to Figures 4-6.
[b]Based on gamma spectrometry analysis.
[c]Calculated using a U-234:U-235 activity ratio of 20:1.
[d]Calculated by adding concentrations of Th-228 and Th-232.
[e]Uncertainties represent the 95% confidence level, based only on counting statistics.
[f]---Indicates analysis was performed by alpha spectrometry; see Table 2.

TABLE 2

ISOTOPIC URANIUM CONCENTRATIONS
IN SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Uranium Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|
| | U-234 | U-235 | U-238 | Total U |
| **Gridline Intersections** | | | | |
| 17N, 75E | 17.1 ± 0.8[c] | 0.9 ± 0.3 | 7.6 ± 0.6 | 25.6 ± 1.0 |
| 20N, 75E | 20.0 ± 0.9 | 0.8 ± 0.2 | 10.3 ± 0.6 | 31.0 ± 1.1 |
| 80N, 60E | 10.4 ± 0.5 | 0.5 ± 0.1 | 7.6 ± 0.4 | 18.5 ± 0.7 |
| **Trench #3** | | | | |
| 80N, E Wall | 17.2 ± 0.7 | 0.9 ± 0.2 | 7.7 ± 0.4 | 25.8 ± 0.8 |
| **Pile #1** | | | | |
| 82N, 80E | 14.6 ± 0.6 | 0.8 ± 0.2 | 6.7 ± 0.4 | 22.1 ± 0.7 |
| **Previously Identified Areas of Elevated Activity** | | | | |
| 70N, 59E | 12.6 ± 0.7 | 0.5 ± 0.2 | 11.6 ± 0.7 | 24.7 ± 1.0 |
| 91N, 42E | 21.7 ± 0.9 | 0.8 ± 0.2 | 10.7 ± 0.6 | 33.2 ± 1.1 |
| **Areas of Elevated Direct Radiation** | | | | |
| 108N, 53E | 66.2 ± 1.4 | 3.2 ± 0.4 | 26.2 ± 0.9 | 95.6 ± 1.7 |
| **Subsurface** | | | | |
| 25N, 70E (0-15 cm) | 22.2 ± 0.8 | 1.4 ± 0.2 | 20.0 ± 0.7 | 43.6 ± 1.1 |
| 55N, 30E (15-40 cm) | 12.0 ± 0.6 | 0.7 ± 0.2 | 7.0 ± 0.4 | 19.7 ± 0.7 |
| 90N, 65E (15-35 cm) | 12.8 ± 0.5 | 0.6 ± 0.1 | 5.3 ± 0.3 | 18.6 ± 0.6 |
| 120N, 35E (110-170 cm) | 0.5 ± 0.1 | 0.1 ± 0.1 | 0.4 ± 0.1 | 0.9 ± 0.2 |

[a]Refer to Figures 4-7.
[b]Based on alpha spectrometry analysis.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics.

TABLE 3

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 25N, 70E | 0-15 | ---[e] | --- | --- | 1.6 |
| | 15-40 | 0.5 ± 0.4[f] | 10.8 ± 1.3 | 21 | 1.8 |
| | 40-80 | 0.3 ± 0.3 | 7.0 ± 1.9 | 13 | 1.4 |
| | 80-130 | 0.3 ± 0.1 | 3.6 ± 0.9 | 9.9 | 1.1 |
| | 130-150 | 0.2 ± 0.1 | 2.6 ± 1.4 | 6.8 | 1.7 |
| 30N, 35E | 0-15 | 0.2 ± 0.1 | 3.4 ± 1.5 | 7.6 | <1.5 |
| | 15-50 | 0.2 ± 0.1 | <1.3 | <5.5 | 1.5 |
| | 50-75 | 0.1 ± 0.1 | 1.8 ± 1.2 | 3.9 | 1.7 |
| | 75-120 | 0.1 ± 0.1 | 2.0 ± 0.9 | 4.1 | 1.4 |
| | 120-150 | 0.3 ± 0.1 | 1.7 ± 1.3 | 8.0 | 1.4 |
| 31N, 60E | 0-15 | 0.3 ± 0.3 | 2.5 ± 1.4 | 8.8 | 2.4 |
| | 15-40 | 0.2 ± 0.1 | 1.1 ± 0.6 | 5.3 | 1.5 |
| | 40-80 | 0.2 ± 0.1 | 1.3 ± 1.0 | 5.6 | 1.7 |
| | 80-130 | 0.2 ± 0.2 | 2.2 ± 1.0 | 6.4 | 1.6 |
| | 130-150 | 0.3 ± 0.3 | <1.7 | <8.0 | 1.2 |
| 45N, 60E | 0-15 | 0.6 ± 0.4 | 7.0 ± 1.2 | 20 | 4.9 |
| | 15-50 | 0.2 ± 0.3 | 2.7 ± 1.0 | 6.9 | 2.0 |
| | 50-90 | 0.2 ± 0.3 | 1.1 ± 0.8 | 5.3 | 2.0 |
| | 90-130 | 0.2 ± 0.1 | 1.9 ± 1.5 | 6.1 | 1.8 |
| | 130-150 | 0.2 ± 0.2 | 1.7 ± 0.7 | 5.9 | 2.0 |
| 50N, 66E | 0-15 | 0.2 ± 0.1 | 1.9 ± 0.7 | 6.1 | 2.0 |
| | 15-45 | 0.2 ± 0.1 | 1.6 ± 1.0 | 5.8 | 1.4 |
| | 45-75 | 0.2 ± 0.2 | 0.8 ± 0.5 | 5.0 | 1.1 |
| 55N, 30E | 0-15 | 0.2 ± 0.1 | 2.1 ± 0.9 | 6.3 | 1.6 |
| | 15-40 | --- | --- | --- | 0.7 |
| | 40-50 | 0.1 ± 0.1 | 0.9 ± 0.6 | 3.0 | 1.1 |
| 70N, 30E | 0-15 | 0.3 ± 0.1 | 2.1 ± 1.7 | 8.4 | 2.0 |
| | 15-40 | 0.2 ± 0.1 | 1.4 ± 0.8 | 5.6 | 2.5 |
| | 40-80 | 0.4 ± 0.4 | 0.4 ± 0.4 | 8.8 | 2.2 |
| | 80-120 | 0.4 ± 0.4 | 2.0 ± 0.8 | 10 | 1.7 |
| | 120-150 | 0.3 ± 0.3 | 2.8 ± 1.4 | 9.1 | 1.8 |

TABLE 3 (Continued)

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 70N, 57E | 0-15 | 0.2 ± 0.2 | 3.6 ± 0.8 | 7.8 | 1.6 |
| | 15-30 | 0.8 ± 0.3 | 10.4 ± 3.1 | 27 | 2.1 |
| 73N, 66E | 0-15 | 0.3 ± 0.2 | 2.7 ± 0.8 | 9.0 | 1.6 |
| | 15-30 | 0.5 ± 0.4 | 4.1 ± 2.1 | 15 | 1.7 |
| 90N, 65E | 0-15 | 0.4 ± 0.2 | 4.8 ± 1.0 | 13 | 1.8 |
| | 15-35 | --- | --- | --- | 1.6 |
| | 35-50 | 0.8 ± 0.3 | 8.6 ± 1.2 | 25 | 1.8 |
| 91N, 27E | 0-15 | 0.4 ± 0.1 | 4.3 ± 1.4 | 12 | 1.6 |
| | 15-40 | 0.3 ± 0.1 | 1.7 ± 0.5 | 8.0 | 1.6 |
| | 40-90 | 0.2 ± 0.1 | 1.7 ± 1.0 | 5.9 | 1.9 |
| | 90-130 | 0.2 ± 0.1 | 1.9 ± 0.8 | 6.1 | 1.8 |
| | 130-150 | <0.5 | <1.9 | <12 | 1.8 |
| 95N, 45E | 0-15 | 0.2 ± 0.1 | 1.9 ± 0.8 | 6.1 | 1.7 |
| | 15-50 | 0.2 ± 0.1 | <1.9 | <6.1 | 1.6 |
| | 50-70 | 0.2 ± 0.1 | 2.4 ± 0.9 | 6.6 | 1.9 |
| | 70-130 | 0.2 ± 0.1 | 1.3 ± 1.2 | 5.4 | 1.5 |
| | 130-150 | 0.7 ± 0.3 | 7.8 ± 1.1 | 23 | 1.5 |
| 95N, 50E | 0-15 | 1.2 ± 0.4 | 7.9 ± 0.8 | 33 | 2.0 |
| | 15-40 | 0.4 ± 0.1 | 4.3 ± 1.7 | 13 | 2.4 |
| | 40-50 | 0.4 ± 0.3 | 5.4 ± 1.2 | 14 | 2.2 |
| 100N, 25E | 0-15 | 0.4 ± 0.3 | 4.3 ± 1.3 | 13 | 2.2 |
| | 15-40 | 0.2 ± 0.1 | 3.8 ± 1.2 | 6.0 | 2.5 |
| | 40-70 | 0.3 ± 0.3 | 2.7 ± 1.0 | 9.0 | 1.5 |
| | 70-120 | 0.2 ± 0.1 | 2.4 ± 1.3 | 6.6 | 1.5 |

TABLE 3 (Continued)

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentration (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[c] | Total Th[d] |
| 105N, 37E | 0-15 | 0.5 ± 0.1 | 4.8 ± 2.2 | 15 | 1.2 |
| | 15-50 | 0.3 ± 0.2 | 3.0 ± 0.8 | 9.3 | 1.0 |
| | 50-80 | 0.2 ± 0.1 | 2.7 ± 1.4 | 6.9 | 1.2 |
| | 80-130 | 0.3 ± 0.1 | 2.2 ± 0.9 | 8.5 | 1.7 |
| 120N, 35E | 0-15 | 0.4 ± 0.1 | 5.2 ± 2.1 | 14 | 2.3 |
| | 15-40 | 0.4 ± 0.1 | 5.8 ± 1.2 | 14 | 2.4 |
| | 40-75 | 0.4 ± 0.4 | 4.5 ± 1.5 | 13 | 1.5 |
| | 75-110 | 0.4 ± 0.1 | 4.8 ± 1.0 | 13 | 1.6 |
| | 110-170 | --- | --- | --- | 1.6 |

[a]Refer to Figure 7.
[b]Based on gamma spectrometry analysis.
[c]Calculated using a U-234:U-235 activity ratio of 20:1.
[d]Calculated by adding concentrations of Th-228 + Th-232.
[e]---Indicate analysis was performed by alpha spectrometry analysis; see Table 2.
[f]Uncertainties represent the 95% confidence level, based only on counting statistics.

TABLE 4

BACKGROUND EXPOSURE RATES
AND RADIONUCLIDE CONCENTRATIONS
IN SOIL
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

| Location[a] | Exposure Rate ($\mu$R/h) at 1 m above the surface | Radionuclide Concentration (pCi/g)[b] | |
|---|---|---|---|
| | | Total U[c] | Total Th[d] |
| 1 | 10 | 1.5 | 1.2 |
| 2 | 9 | 1.3 | 1.1 |
| 3 | 9 | <1.7 | 0.9 |
| 4 | 10 | 2.0 | 1.4 |
| 5 | 10 | 1.9 | 1.9 |
| 6 | 10 | <1.2 | 2.1 |
| Average | 10 | 1.6 | 1.4 |

[a]Refer to Figure 8.
[b]Based on gamma spectrometry analysis.
[c]Calculated based on natural activity ratios.
[d]Calculated by adding concentrations of Th-228 + Th-232.

## REFERENCES


1. "Interim Report of Confirmatory Survey of Portions of the Sequoyah Fuels Corporation Cimarron Plant, Crescent Oklahoma," ORAU, January 1989.

2. "Cimarron Facility, Contaminated Waste Burial Ground Decontamination and Final Survey Report", Cimarron Corporation, November 1991.

3. "Confirmatory Radiological Survey Plan for the On-Site Burial Ground of the Cimarron Corporation Facility, Crescent, Oklahoma," ORAU, November 1991.

4. "Policy and Guideline Directive FC91-2, Standard Review Plan: Evaluating Decommissioning Plans for Licenses Under 10 CFR Parts 30, 40, and 70," U.S. Nuclear Regulatory Commission, August 1991.

# APPENDIX A

# MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

# APPENDIX A

## MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

### A. Direct Radiation Measurements

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, OH)

Reuter-Stokes Pressurized Ionization Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

### B. Laboratory Analytical Equipment

High-Purity Germanium Coaxial Well Detector
Model GWL-1102010-PWS-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Applied Physical Technology, Atlanta, GA)

Multichannel Analyzer
ND-66/Micro VaxII
(Nuclear Data, Schaumburg, IL/Digital Equipment Corp., Maynard, MA)

Alpha Spectrometry System
Tennelec Electronics
(Tennelec, Oak Ridge, TN)

Solid State Surface Barrier Detectors
(EG&G Ortec, Oak Ridge, TN)
(Tennelec, Oak Ridge, TN)

Multichannel Analyzer
ND-66
(Nuclear Data, Schaumberg, IL)

# APPENDIX B

# MEASUREMENT AND ANALYTICAL PROCEDURES

# APPENDIX B

# MEASUREMENT AND ANALYTICAL PROCEDURES

## Surface Scans

Surface scans were conducted using NaI scintillation detectors with ratemeters. The scans were performed by passing the probes slowly over the surface; the distance between the probe and the surface was maintained nominally at about 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument.

## Gamma Exposure Rate Measurements

Measurements of gamma exposure rates were performed using portable ratemeters with gamma scintillation detectors. Count rates were converted to exposure rates ($\mu$R/h) by cross-calibrating with a pressurized ion chamber.

## Gamma Spectroscopy

The samples were placed in an appropriate container chosen to reproduce the calibrated counting geometry. Net weights were determined and the samples counted using high purity intrinsic germanium detectors coupled to a Nuclear Data Model ND-66/Micro VaxII pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks, used for determination of radionuclides of concern, were:

| | |
|---|---|
| U-238 | 0.093 MeV from Th-234* |
| U-235 | 0.143 MeV |
| Th-228 | 0.583 MeV from Tl-208* |
| Th-232 | 0.911 MeV from Ac-228* |

*Secular equilibrium assumed.

Spectra were reviewed for other identifiable photopeaks at concentrations above those normally encountered in environmental media.

## Alpha Spectroscopy

Soil samples were dried and homogenized, and aliquots were dissolved by pyrosulfate fusion and precipitated by barium sulphate. The barium sulphate precipitate was redissolved and the uranium was separated by liquid-liquid extraction. The uranium was then precipitated with a cerium fluoride carrier and counted using surface barrier detectors, alpha spectrometers, and a ND-66 multichannel analyzer.

## Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report represent the 95% confidence level for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net sample count was less than the 95% statistical deviation of the background count, the sample concentration was reported as less than the detection limit of the measurement procedure. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument. Additional uncertainties of $\pm$ 6 to 10%, associated with laboratory procedures, have not been propagated into the data presented in this report.

## Quality Assurance

Analytical and field survey activities were conducted in accordance with procedures from the following documents:

- Survey Procedures Manual, Revision 6, February 1991
- Quality Assurance Manual, Revision 4, April 1991
- Laboratory Procedures Manual, Revision 6, April 1991

The procedures contained in these manuals were developed to meet the requirements of DOE Order 5700.6B.

Calibration of all field laboratory instrumentation is based on NIST-traceable standards, when such standards are available. In cases where they are not available, standards of an industry recognized organization will be used. Calibration of pressurized ionization chambers is performed by the manufacturer.

Quality Control procedures include:

- Daily instrument background and check-source measurements to confirm that the equipment operation is within acceptable statistical fluctuations
- Participation in EPA and EML Quality Assurance Programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

# APPENDIX C

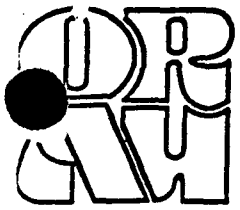
# GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

## Guidelines for Residual Concentrations of Thorium and Uranium Wastes in Soil

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

| Material | Maximum Concentrations (pCi/g) for various options | | | |
|---|---|---|---|---|
| | 1[a] | 2[b] | 3[c] | 4[d] |
| Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium | 10 | 50 | --- | 500 |
| Natural Uranium (U-238 + U-234) with daughters present and in equilibrium | 10 | -- | 40 | 200 |
| Depleted Uranium: | | | | |
| Soluble | 35 | 100 | --- | 1,000 |
| Insoluble | 35 | 300 | --- | 3,000 |
| Enriched Uranium: | | | | |
| Soluble | 30 | 100 | --- | 1,000 |
| Insoluble | 30 | 250 | --- | 2,500 |

[a]Based on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 3 mrad/yr to bone from ingestion and inhalation and 10 $\mu$R/h above background from direct external exposure.
[b]Based on limiting individual dose to 170 mrem/yr.
[c]Based on limiting equivalent exposure to 0.02 working level or less.
[d]Based on limiting individual dose to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.



Prepared by
Oak Ridge Associated Universities

Prepared for
U.S. Nuclear Regulatory Commission's Region III Office

Sponsored by
Division of Industrial and Medical Nuclear Safety

# CONFIRMATORY RADIOLOGICAL SURVEY OF THE SANITARY LAGOONS AT THE CIMARRON CORPORATION FACILITY CRESCENT, OKLAHOMA

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**CONFIRMATORY RADIOLOGICAL SURVEY OF THE SANITARY LAGOONS AT THE CIMARRON CORPORATION FACILITY CRESCENT, OKLAHOMA**

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# CONFIRMATORY RADIOLOGICAL SURVEY OF THE SANITARY LAGOONS AT THE CIMARRON CORPORATION FACILITY CRESCENT, OKLAHOMA

## INTRODUCTION

Beginning in 1965, the Kerr-McGee Corporation operated a plant in Crescent, Oklahoma, under AEC/NRC license SNM-928 to produce slightly enriched (about 3%) uranium fuel. Another facility for production of plutonium and mixed oxide (uranium plus plutonium) fuel began operation at the same site in 1970. In 1983, Sequoyah Fuels Corporation (SFC) became the owner of the Cimarron Facility when Kerr-McGee Nuclear Corporation was divided into SFC and Quivira Mining Corporation. Later, Cimarron Corporation, a subsidiary of the Kerr-McGee Nuclear Corporation, became responsible for the Cimarron Facility.

Decontamination of the Cimarron Facility began during 1979 with the goal of removing all contaminated equipment and materials so that the facility could be released for unrestricted use. The decontamination and decommissioning project was divided into several tasks, which involved the Plutonium Plant, the Uranium Plant, the On-Site Burial Ground, and the Sanitary Lagoons. Decontamination and decommissioning activities involving the Plutonium Plant and the On-Site Burial Ground are nearing completion, and the Uranium Plant is in the process of being decontaminated. Decontamination activities have been completed for the East and West Sanitary Lagoons. Contaminated sludge from the Sanitary Lagoons has been removed and shipped offsite.

A final release survey of these lagoons, performed by Cimarron Corporation, indicates that residual radioactive contamination is within the NRC guidelines for unrestricted release.

At the request of the NRC Office, Region III, the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities (ORAU) conducted a radiological survey of the East and West Sanitary Lagoons to confirm that these areas meet the guidelines established for decommissioning.

## FACILITY DESCRIPTION

The Cimarron Facility is located on a site of approximately 450 hectares in Logan County, Oklahoma, about 8 kilometers south of the town of Crescent (Figures 1 and 2). The site consisted of the Uranium Plant, the Plutonium Plant, an Onsite Burial Ground for low level wastes, two Sanitary Lagoons, and a Waste Evaporation Pond. The East and West Sanitary Lagoons occupy an area of approximately 6600 square meters, surrounded by an access control fence. The lagoons have a surrounding berm and are approximately 1.5 to 5 m deep. The area is mostly red clay, with shale and sandstone beneath.

## PROCEDURES

### Objective

The objective of the survey was to perform a radiological assessment of the East and West Sanitary Lagoons and to provide sufficient data to confirm that decontamination and decommissioning efforts by Cimarron Corporation were effective in meeting the NRC guidelines for unrestricted release.

## Survey Procedures

During the period of November 5 - 6, 1990, the Environmental Survey and Site Assessment Program (ESSAP) of ORAU conducted an independent radiological survey of the East and West Sanitary Lagoons. The survey was performed in accordance with a plan developed by ORAU and submitted to the NRC.

### Gridding

Detailed grid maps were provided to ESSAP by Cimarron Corporation prior to implementing survey activities. The reference grid system established by Cimarron Corporation was utilized.

### Surface Scans

Gamma surface scans were performed at 2 m intervals in both of the lagoons and throughout the remainder of the fenced area. Scans were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters with audible indicators. Locations of elevated direct radiation were noted for further investigation.

### Soil Sampling

Surface soil samples (depth 0-15 cm) were collected at 20 m intervals and at locations of elevated contact radiation, identified by the surface scan. Sampling locations are indicated in Figure 3.

## Borehole Sampling

Shallow boreholes were drilled at 12 locations in the East and West Sanitary Lagoons (Figure 4). The depth of the holes ranged from 0.4 m to 1.5 m. Thirty-six soil samples were collected at various depths from the 12 holes. A water sample was obtained from one of the boreholes (Figure 5); all other boreholes were dry.

## Exposure Rate Measurements

Exposure rate measurements were obtained where surface soil or borehole soil samples were taken (Figures 3 and 4). Measurements were performed at the surface (contact) and at 1 m above the surface. Measurements were obtained using NaI(Tl) gamma scintillation detectors coupled to ratemeters, and cross-calibrated with a pressurized ion chamber (PIC). Additional measurements were performed at seven locations in and around the Sanitary Lagoons using a PIC (Figure 6).

## Confirmatory Soil Samples

Ten soil samples which had been previously collected and analyzed by Cimarron Corporation were obtained by ORAU for confirmatory analysis. These samples were collected from various locations and depths within the two Sanitary Lagoons (Figure 7).

## Sample Analysis and Data Interpretation

Soil samples were analyzed by solid state gamma spectroscopy for uranium. Spectra were also reviewed for other identifiable photopeaks. Approximately 10% of the soil samples

were analyzed by alpha spectroscopy for uranium and plutonium. The water sample was analyzed for gross alpha and beta activity. Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B. Results of the independent measurements were compared to the NRC guidelines (Appendix C).[1]

## FINDINGS AND RESULTS

### Surface Scans

Surface scans for gamma activity identified one location of elevated direct radiation (Figure 3). This area was small and isolated, and was removed with the collection of a soil sample. Table 1 provides the initial and follow-up measurement results for this location. Remediation (i.e., collecting a surface soil sample) was effective in reducing the radiation levels to near background levels.

### Exposure Rate Measurements

Exposure rate measurements at 1 meter above the surface ranged from 9 to 12 $\mu$R/h for the East Lagoon and from 10 to 11 $\mu$R/h for the West Lagoon. Contact exposure rate measurements ranged from 9 to 12 $\mu$R/h for the East Lagoon and from 10 to 13 $\mu$R/h for the West Lagoon. For comparison, area background levels of 9 to 10 $\mu$R/h were determined during earlier surveys of the site.[2]

### Radionuclide Concentrations

The radionuclide concentrations determined for the surface soil samples collected from the area of elevated direct radiation are presented in Table 1. The initial sample contained concentrations of 6800 pCi/g of U-235 and 8700 pCi/g of U-238.

These uranium concentrations are atypical of the uranium concentrations that were present on-site and should not be considered as representative of the contamination which was present in the lagoons. The follow-up sample contained uranium concentrations of 0.3 pCi/g of U-235 and 3.3 pCi/g of U-238.

The radionuclide concentrations determined for surface soil samples are presented in Table 2. Ranges of uranium concentrations were 0.1 to 1.5 pCi/g for U-235 and 1.4 to 11.0 pCi/g for U-238. Concentrations of plutonium were $<0.3$ pCi/g for Pu-238 and Pu-239/240. Total uranium concentrations were calculated using a ratio of total uranium to U-238 activity of 4.9 to 1; the resulting concentrations ranged from 6.9 pCi/g to 53.9 pCi/g.

The radionuclide concentrations determined for soil samples collected from boreholes are presented in Table 3. Uranium concentrations ranged from 0.1 to 2.1 pCi/g for U-235 and from 0.8 to 13 pCi/g for U-238. Plutonium concentrations were $<0.3$ pCi/g for Pu-238 and $<0.2$ pCi/g for Pu-239/240. Total uranium concentrations ranged from 3.9 pCi/g to 63.7 pCi/g.

The results of the water sample analysis were $15.6 \pm 1.9$ pCi/g gross alpha activity and $8.1 \pm 1.4$ pCi/g gross beta activity.

The radionuclide concentrations obtained by ORAU for the ten confirmatory soil samples collected by Cimarron Corporation are presented in Tables 4 and 5. Ranges of uranium concentrations were 0.6 to 1.3 pCi/g for U-235 and 5.6 to 8.1 pCi/g for U-238. Plutonium concentrations were $<0.07$ pCi/g for Pu-238 and $<0.1$ pCi/g for Pu-239/240. The ranges of total uranium concentrations were 27.4 to 39.7 pCi/g for the ORAU analyses and 20.3 to 25.0 pCi/g for the Cimarron Corporation analyses.

## COMPARISON OF RESULTS WITH GUIDELINES

Appendix C presents the NRC Guidelines for Residual Concentrations of Thorium and Uranium Wastes in Soil. The guideline value for total uranium enriched in U-235 is 30 pCi/g.

The only area of elevated direct radiation identified by gamma scans was located in the East Sanitary Lagoon. The direct radiation level was reduced to background levels with the collection of a soil sample. The results of the follow-up sample collected in this location indicate that the area now meets the NRC guideline.

The total uranium concentrations of all systematic surface soil samples were within the 30 pCi/g guideline value, with the exception of the sample obtained from 160E, 260N. The total uranium concentration of this sample was 53.9 pCi/g. Although this sample was above the guideline value, other samples obtained from adjacent areas contain much lower concentrations, and the average levels for this area may be within the guideline value. No detectable concentrations of plutonium were indicated.

Two samples collected from boreholes exceeded the NRC guideline level. These samples were collected at 135E, 260N (depth 0-15 cm) and 165E, 220N (depth 0-15 cm). The total uranium concentrations of these samples were 63.7 and 49.0 pCi/g, respectively. These samples were collected at the surface. Additional samples collected at greater depths from the same boreholes were well within the guideline value. Hence, it appears that the residual contamination was present in the surface (0-15 cm) layer only. Averaging with samples from adjacent areas, which contain much lower concentrations, may provide results within the guideline value. No detectable concentrations of plutonium were indicated.

The water sample collected from the borehole located at 165E, 220N indicated gross alpha and gross beta activity typical of background concentrations.

Exposure rates in the East and West Sanitary Lagoons ranged from 9 to 12 $\mu$R/h which is well within the guideline value of 10 $\mu$R/h above background.

Nine of the ten samples collected by Cimarron Corporation for confirmatory analysis failed to meet the guideline level of 30 pCi/g total uranium. Using the activity ratio of 4.9:1 for Total U:U-238, the total uranium (U-234, U-235, and U-238) concentration in these nine samples ranged from 33.3 to 39.7 pCi/g. The one sample that was below the guideline level had a total uranium concentration of 27.4 pCi/g. The total uranium concentrations determined by ORAU for these samples were all higher than the values reported by Cimarron Corporation. Ratios of ORAU to Cimarron values ranged from 1.3 to 1.8 with an average ratio of about 1.6. Although the ORAU total uranium values have associated $2\sigma$ uncertainties, typically on the order of 25% or greater, because all ORAU levels are higher than the corresponding Cimarron levels, this suggests an overall bias in the analysis. This ratio is within the values determined by a previous ORAU-Cimarron Corporation sample analysis comparison.[3]

## SUMMARY

At the request of the Nuclear Regulatory Commission, Region III, the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities conducted an independent radiological survey of the Sanitary Lagoons of the Cimarron Corporation, Cimarron Facility from November 5 - 6, 1990. The survey included gamma scans and determination of radionuclide concentrations in surface soil samples, borehole soil samples, a water sample, and soil samples provided by Cimarron Corporation for confirmatory analysis.

The survey identified one small area of elevated direct surface gamma radiation. This was due to a small piece of material, which was removed by sampling; the sampling reduced the direct radiation and soil concentration levels to background values. One surface soil sample and two borehole soil samples contained total uranium exceeding the 30 pCi/g guideline. However, other samples from adjacent areas contained concentrations well below the guideline value and average concentrations are, therefore within the guideline.

Confirmatory analyses on nine samples suggest that Cimarron analyses may be low. The average discrepancy is about 60%. While this discrepancy would result in underestimating the total residual uranium inventory at the site, the soil concentrations are low enough that, even if a 60% correction were applied to the data, the average concentration would still be below the 30 pCi/g guideline value.

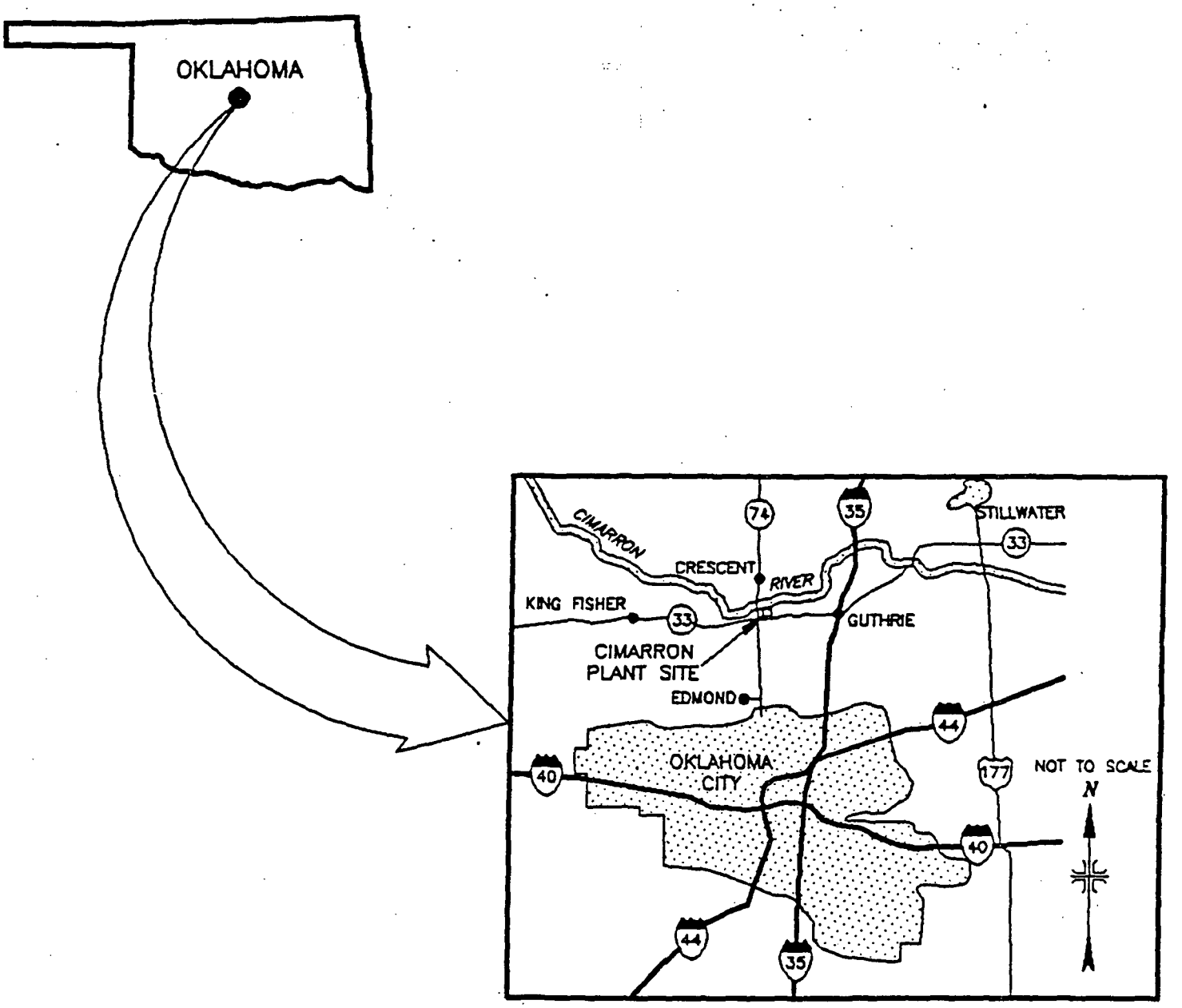


FIGURE 1: Location of the Cimarron Facility, Crescent, Oklahoma

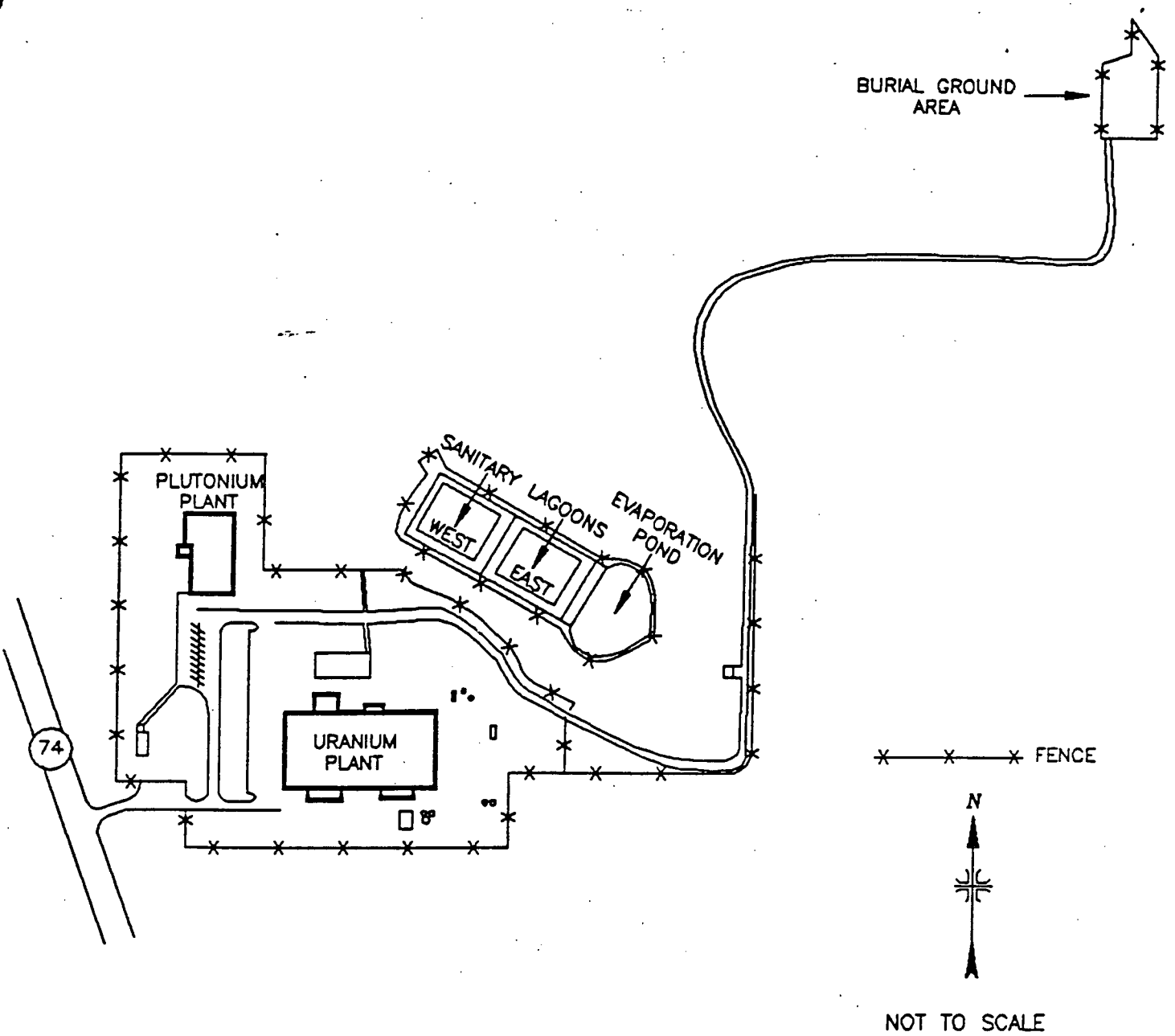


FIGURE 2: Plot Plan of the Cimarron Facility

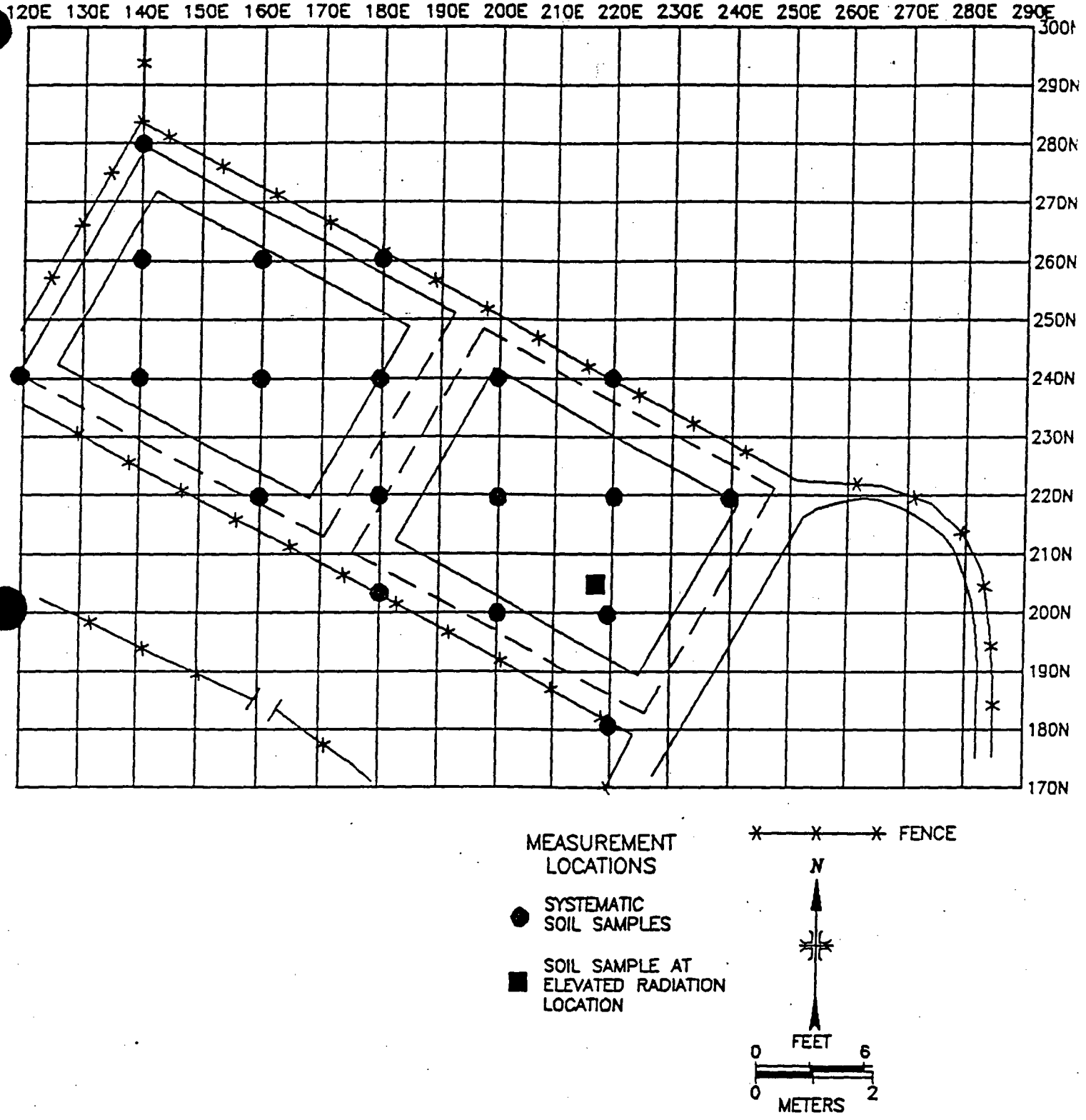


FIGURE 3: East and West Sanitary Lagoons: Surface Soil Sampling Locations

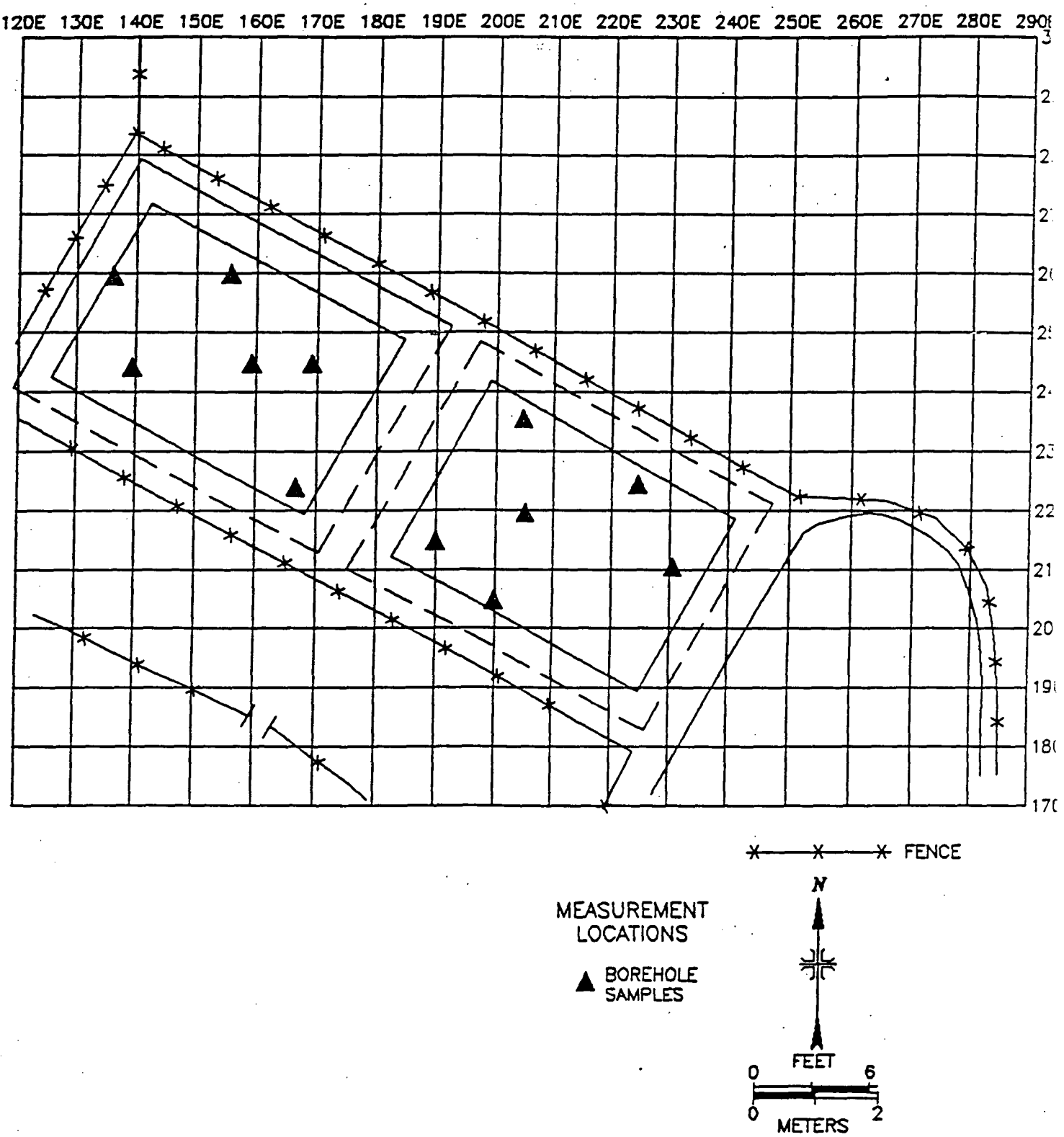


FIGURE 4: East and West Sanitary Lagoons: Borehole Soil Sampling Locations

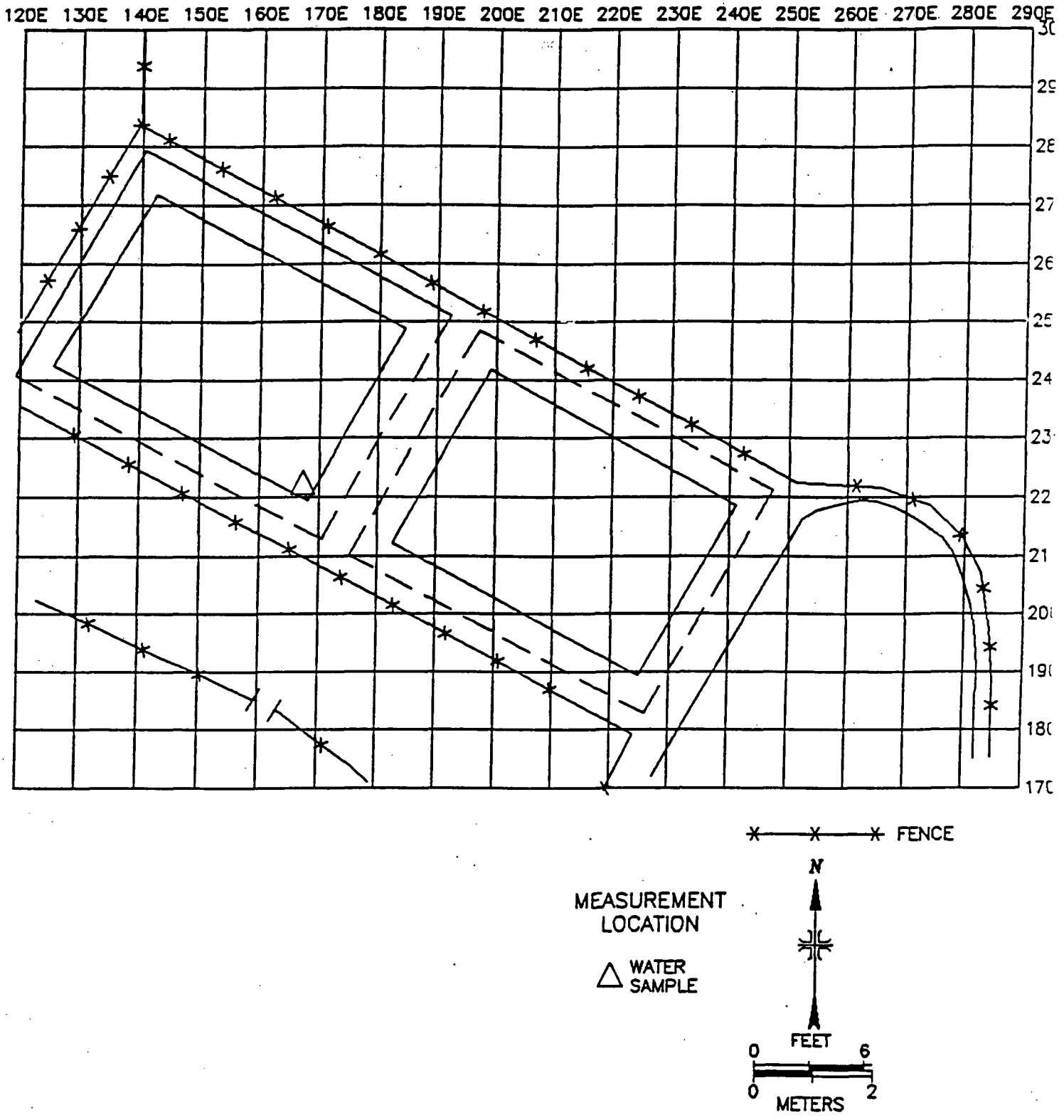


FIGURE 5: East and West Sanitary Lagoons: Water Sampling Location

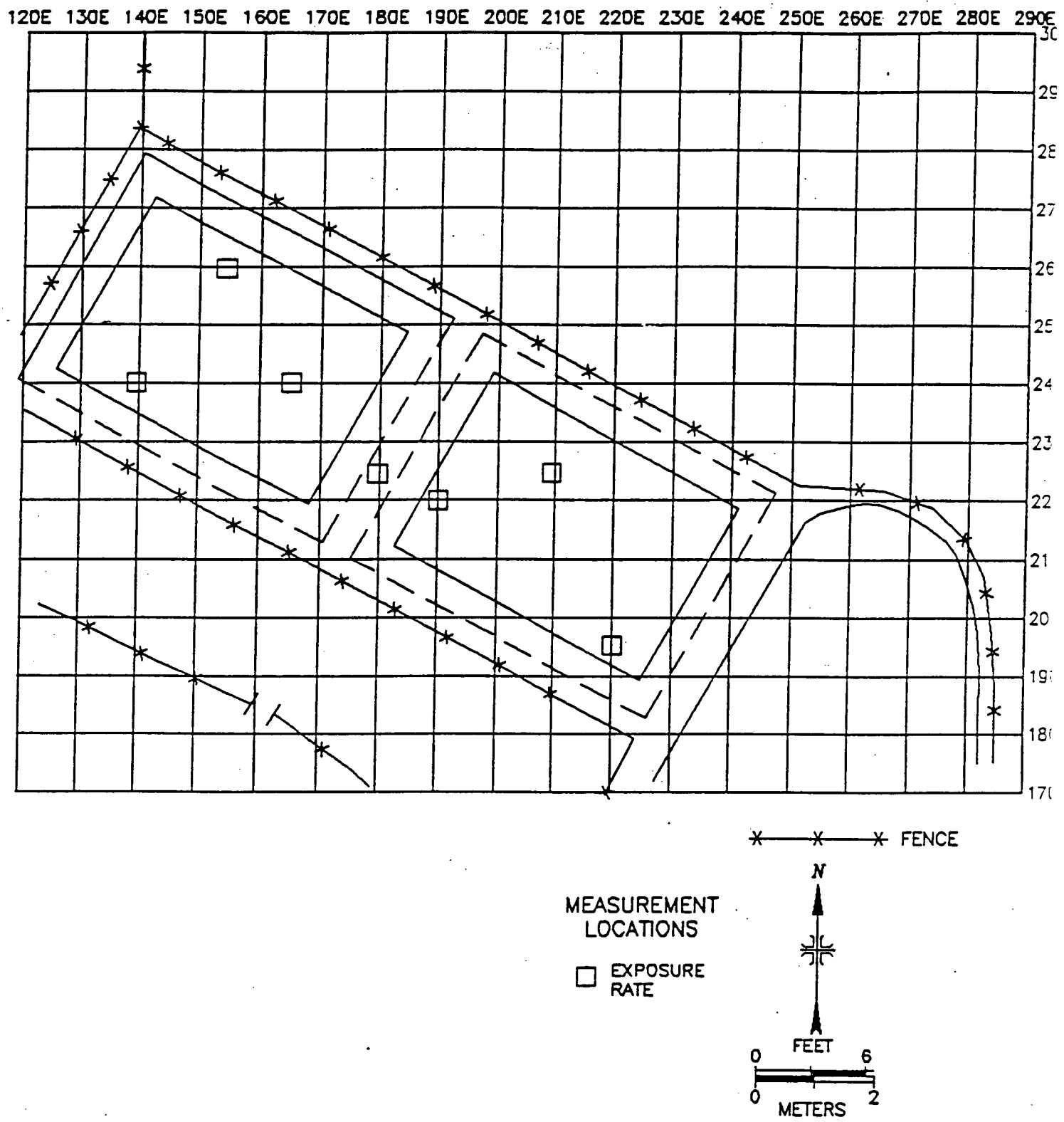


FIGURE 6: East and West Sanitary Lagoons:
Exposure Rate Measurement Locations

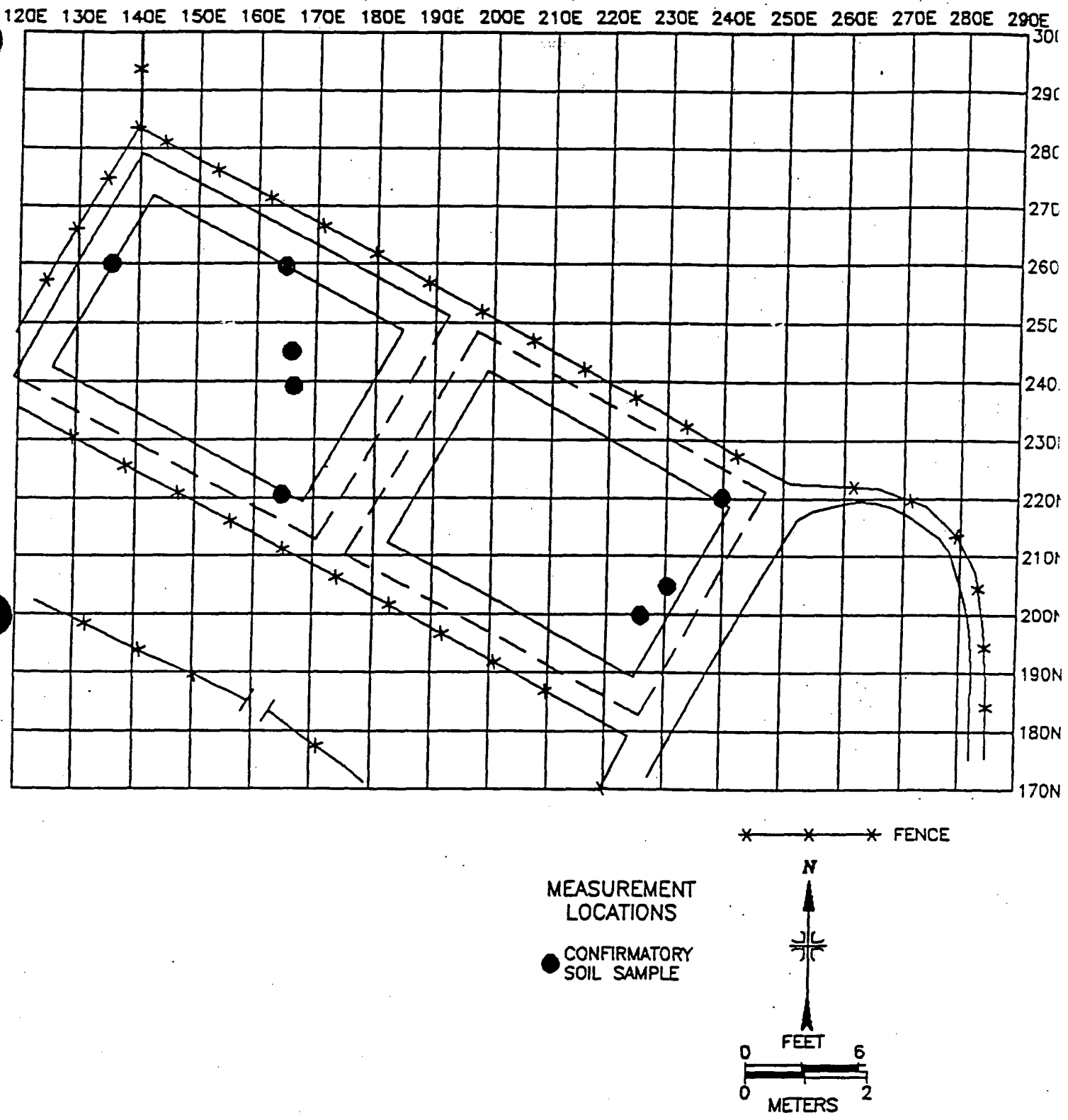


FIGURE 7: Soil Sampling Locations for Confirmatory Analysis

## TABLE 1

## URANIUM CONCENTRATIONS IN SOIL SAMPLES COLLECTED FROM LOCATIONS OF ELEVATED DIRECT RADIATION SANITARY LAGOONS CIMARRON CORPORATION CRESCENT, OKLAHOMA

| Location[a] | μR/h | Depth | Uranium Concentrations (pCi/g) | |
|---|---|---|---|---|
| | | | U-235 | U-238 |
| **Initial** 220E, 193N | 292 | 0-15 cm | 6800 ± 100[bc] | 8700 ± 150[c] |
| **Follow-Up** 220E, 193N | 12 | 0-15 cm | 0.3 ± 0.3 | 3.3 ± 1.5 |

[a]Refer to Figure 3.

[b]Uncertainties represent the 95% confidence level, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

[c]These levels are atypical of the concentrations which have been found on-site and should not be considered representative of the contamination which was present.

## TABLE 2

## RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
## SANITARY LAGOONS
## CIMARRON CORPORATION
## CRESCENT, OKLAHOMA

| Locations[a] | Radionuclide Concentrations (pCi/g) | | | | |
|---|---|---|---|---|---|
| | U-235 | U-238 | Total U[b] | Pu-238 | Pu-239/240 |
| 140E, 280N | 0.2 ± 0.1[c] | 2.4 ± 1.1 | 11.8 | <0.3 | <0.2 |
| 140E, 260N | 0.4 ± 0.3 | 4.1 ± 1.4 | 20.1 | ---[d] | --- |
| 140E, 240N | 0.5 ± 0.4 | 1.6 ± 0.8 | 7.8 | --- | --- |
| 120E, 240N | 0.7 ± 0.4 | 4.4 ± 1.6 | 21.6 | --- | --- |
| 160E, 220N | 0.2 ± 0.4 | 1.4 ± 0.2 | 6.9 | --- | --- |
| 160E, 240N | 0.3 ± 0.3 | 3.4 ± 1.0 | 16.7 | <0.3 | <0.2 |
| 160E, 260N | 1.5 ± 0.4 | 11.0 ± 2.0 | 53.9 | --- | --- |
| 180E, 260N | 0.4 ± 0.4 | 2.8 ± 1.1 | 13.7 | --- | --- |
| 180E, 240N | 0.1 ± 0.1 | 1.8 ± 1.4 | 8.8 | --- | --- |
| 180E, 220N | 0.2 ± 0.1 | 1.9 ± 1.0 | 9.3 | --- | --- |
| 180E, 200N | 0.3 ± 0.3 | 1.4 ± 0.9 | 6.9 | --- | --- |
| 200E, 200N | 0.2 ± 0.3 | 2.2 ± 1.1 | 10.8 | --- | --- |
| 200E, 220N | 0.2 ± 0.1 | 2.1 ± 1.1 | 10.3 | --- | --- |
| 200E, 240N | 0.4 ± 0.3 | 2.0 ± 1.0 | 9.8 | --- | --- |

## TABLE 2 (Con't)

## RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
## SANITARY LAGOONS
## CIMARRON CORPORATION
## CRESCENT, OKLAHOMA

| Locations[a] | Radionuclide Concentrations (pCi/g) | | | | |
|---|---|---|---|---|---|
| | U-235 | U-238 | Total U[b] | Pu-238 | Pu-239/240 |
| 220E, 240N | 0.3 ± 0.3 | 3.2 ± 1.2 | 15.7 | --- | --- |
| 220E, 220N | 0.4 ± 0.4 | 2.1 ± 0.8 | 10.3 | --- | --- |
| 220E, 200N | 0.3 ± 0.3 | 3.3 ± 1.5 | 16.2 | --- | --- |
| 220E, 180N | 0.3 ± 0.1 | 2.0 ± 1.0 | 9.8 | <0.2 | <0.3 |
| 240E, 220N | 0.5 ± 0.3 | 4.4 ± 1.2 | 21.6 | --- | --- |

[a]Refer to Figure 3.
[b]Calculated utilizing Total U: U-238 activity ratio of 4.9:1.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.
[d]---Analysis not performed.

## TABLE 3

## RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
## SANITARY LAGOONS
## CIMARRON CORPORATION
## CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentrations (pCi/g) | | | | |
|---|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[b] | Pu-238 | Pu-239/240 |
| 135E, 260N | 0- 15 | 2.1 ± 0.5[c] | 13.0 ± 1.9 | 63.7 | ---[d] | --- |
| | 15- 40 | 0.1 ± 0.1 | 0.8 ± 0.9 | 3.9 | --- | --- |
| 140E, 245N | 0- 15 | 0.6 ± 0.5 | 3.8 ± 1.2 | 18.6 | --- | --- |
| | 15- 50 | 0.2 ± 0.1 | <2.2 | <10.8 | --- | --- |
| 155E, 260N | 0- 15 | 0.3 ± 0.3 | 3.4 ± 1.2 | 16.7 | --- | --- |
| | 15- 50 | 0.1 ± 0.1 | 2.2 ± 0.9 | 10.8 | --- | --- |
| 160E, 245N | 0- 15 | 0.5 ± 0.3 | 3.3 ± 1.5 | 16.2 | --- | --- |
| | 15- 50 | 0.2 ± 0.1 | 1.6 ± 0.9 | 7.8 | --- | --- |
| | 50-100 | 0.1 ± 0.1 | 1.8 ± 1.1 | 8.8 | --- | --- |
| 165E, 220N | 0- 15 | 2.0 ± 0.5 | 10.0 ± 1.9 | 49.0 | --- | --- |
| | 15- 30 | 0.3 ± 0.1 | 1.7 ± 0.9 | 8.3 | --- | --- |
| | 30- 50 | 0.3 ± 0.1 | 2.5 ± 1.4 | 12.3 | <0.09 | <0.1 |
| | 50- 90 | 0.2 ± 0.1 | 2.1 ± 0.9 | 10.3 | --- | --- |
| 170E, 245N | 0- 15 | 0.6 ± 0.4 | 3.1 ± 1.2 | 15.2 | --- | --- |
| | 15- 50 | 0.1 ± 0.3 | 2.2 ± 1.0 | 10.8 | --- | --- |
| | 50-100 | 0.2 ± 0.1 | 1.9 ± 1.2 | 9.3 | --- | --- |

TABLE 3 (Con't)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
SANITARY LAGOONS
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentrations (pCi/g) | | | | |
|---|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[b] | Pu-238 | Pu-239/240 |
| 190E, 215N | 0- 15 | 0.9 ± 0.4 | 3.3 ± 0.9 | 16.2 | --- | --- |
| | 15- 45 | 0.2 ± 0.1 | 1.7 ± 1.2 | 8.3 | --- | --- |
| 200E, 205N | 0- 15 | 0.3 ± 0.3 | 1.8 ± 1.2 | 8.8 | --- | --- |
| | 15- 50 | 0.5 ± 0.6 | 2.7 ± 1.5 | 13.2 | <0.1 | <0.05 |
| | 50-100 | 0.2 ± 0.1 | 1.5 ± 1.1 | 7.4 | --- | --- |
| | 100-120 | 0.1 ± 0.1 | <1.5 | 7.4 | --- | --- |
| 205E, 220N | 0- 15 | 0.5 ± 0.3 | 1.9 ± 1.0 | 9.3 | --- | --- |
| | 15- 50 | 0.3 ± 0.1 | 2.2 ± 1.4 | 10.8 | --- | --- |
| 205E, 235N | 0- 15 | 0.2 ± 0.1 | 1.1 ± 1.1 | 5.4 | --- | --- |
| | 15- 50 | 0.1 ± 0.1 | 2.2 ± 1.1 | 10.8 | --- | --- |
| | 50-100 | 0.1 ± 0.1 | <1.8 | <8.8 | --- | --- |
| | 100-150 | 0.1 ± 0.1 | 1.3 ± 0.8 | 6.4 | <0.3 | <0.2 |
| 225E, 225N | 0- 15 | 0.8 ± 0.5 | 3.5 ± 1.5 | 17.2 | --- | --- |
| | 15- 70 | 0.5 ± 0.4 | 2.8 ± 1.4 | 13.7 | --- | --- |
| | 70-100 | 0.4 ± 0.1 | 3.1 ± 1.0 | 15.2 | --- | --- |
| | 100-150 | 0.2 ± 0.1 | 1.5 ± 0.7 | 7.4 | --- | --- |

TABLE 3 (Con't)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
SANITARY LAGOONS
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentrations | | | | |
|---|---|---|---|---|---|---|
| | | U-235 | U-238 | Total U[b] | Pu-238 | Pu-239/240 |
| 230E, 210N | 0- 15 | 0.3 ± 0.1 | 2.1 ± 1.3 | 10.3 | --- | --- |
| | 15- 50 | 0.3 ± 0.3 | 1.4 ± 1.1 | 6.9 | --- | --- |
| | 50-100 | 0.2 ± 0.1 | 1.5 ± 1.4 | 7.4 | --- | --- |
| | 100-125 | 0.1 ± 0.1 | 0.8 ± 0.9 | 3.9 | --- | --- |

[a]Refer to Figure 4.
[b]Calculated utilizing Total U: U-238 activity ratio of 4.9:1.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.
[d]--- Analysis not performed.

## TABLE 4

## RADIONUCLIDE CONCENTRATIONS IN CONFIRMATORY SOIL SAMPLES
## SANITARY LAGOONS
## CIMARRON CORPORATION
## CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|
| | | U-235 | U-238 | Pu-238 | Pu-239/240 |
| 200N, 225E | 0-15 | 1.2 ± 0.5[b] | 6.9 ± 2.0 | <0.07 | <0.1 |
| 205N, 230E | 0-15 | 1.3 ± 0.5 | 8.1 ± 1.8 | ---[c] | --- |
| 220N, 165E | 0-15 | 1.3 ± 0.6 | 7.4 ± 1.6 | --- | --- |
| 220N, 165E | 15-30 | 1.2 ± 0.5 | 8.0 ± 1.9 | <0.06 | <0.06 |
| 220N, 240E | 30-60 | 1.1 ± 0.7 | 7.0 ± 1.5 | --- | --- |
| 240N, 165E | 0-15 | 0.6 ± 0.5 | 5.6 ± 1.4 | --- | --- |
| 245N, 165E | 0-15 | 0.6 ± 0.5 | 7.4 ± 2.3 | --- | --- |
| 260N, 165E | 0-15 | 1.0 ± 0.5 | 7.3 ± 2.0 | --- | --- |
| 260N, 165E | 15-30 | 0.9 ± 0.4 | 6.8 ± 2.4 | --- | --- |
| 260N, 135E | 15-30 | 0.7 ± 0.4 | 7.4 ± 2.0 | --- | --- |

[a]Refer to Figure 7.
[b]Uncertainties represent the 95% confidence level, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.
[c]--- Analysis not performed.

## TABLE 5

## TOTAL URANIUM CONCENTRATIONS IN CONFIRMATORY SOIL SAMPLES
## SANITARY LAGOONS
## CIMARRON CORPORATION
## CRESCENT, OKLAHOMA

| Location[a] | Depth (cm) | Total Uranium Concentration (pCi/g) | |
|---|---|---|---|
| | | ORAU[b] | Cimarron |
| 200N, 225E | 0-15 | 33.8 | 21.6 |
| 205N, 230E | 0-15 | 39.7 | 25.0 |
| 220N, 165E | 0-15 | 36.3 | 20.3 |
| 220N, 165E | 15-30 | 39.2 | 23.5 |
| 220N, 240E | 30-60 | 34.3 | 22.6 |
| 240N, 165E | 0-15 | 27.4 | 20.8 |
| 245N, 165E | 0-15 | 36.3 | 22.8 |
| 260N, 165E | 0-15 | 35.8 | 20.3 |
| 260N, 165E | 15-30 | 33.3 | 21.7 |
| 260N, 135E | 30-60 | 36.3 | 22.1 |

[a]Refer to Figure 7.
[b]ORAU measurements calculated utilizing Total U:U-238 activity ratio of 4.9:1.

## REFERENCES


1. "Guidelines for Residual Concentration of Thorium and Uranium Wastes in Soil," U.S. Nuclear Regulatory Commission, October 1981.

2. "Confirmatory Survey of the Cimarron Corporation Mixed Oxide Fuel Fabrication Plant, Crescent, Oklahoma," Oak Ridge Associated Universities, January 1991.

3. Berger, J. letter to D. Hurt, Division of Industrial and Medical Nuclear Safety, U.S. Nuclear Regulatory Commission, dated August 31, 1989.

# APPENDIX A

# MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

## APPENDIX A

## MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

### I. DIRECT RADIATION MEASUREMENT

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Eberline Beta Gamma "Pancake" Detector
Model HP-260
(Eberline, Santa Fe, NM)

Ludlum Ratemeter-Scaler
Model 2221
(Ludlum, Sweetwater, TX)

Reuter-Stokes Pressurized Ion Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, OH)

### II. LABORATORY ANALYTICAL EQUIPMENT

Low Background Alpha-Beta Counter
Model LB-5110
(Tennelec, Oak Ridge, TN)

High Purity Germanium Coaxial Well Detector
Model GWL-1102010-PWS-S, 23% efficiency
(EG&G Ortec, Oak Ridge, TN)

Used in conjunction with:
Lead Shield Model G-16
(Applied Physical Technology, Atlanta, Ga)

Multichannel Analyzer
ND-66/MicroVax
(Nuclear Data, Schaumberg, IL/Digital Equipment Corp., Maynard, MA)

Alpha Spectrometry System
Tennelec Electronics
(Tennelec, Oak Ridge, TN)

Solid State Surface Barrier Detectors
(EG&G Ortec, Oak Ridge, TN)
(Tennelec, Oak Ridge, TN)

Multichannel Analyzer
ND-66
(Nuclear Data, Schaumberg, IL)

# APPENDIX B

# MEASUREMENT, SAMPLING, AND ANALYTICAL PROCEDURES

# APPENDIX B

# MEASUREMENT, SAMPLING, AND ANALYTICAL PROCEDURES

## Surface Scans

Gamma scans were performed using Victoreen NaI scintillation detectors with Eberline PRM-6 ratemeters. Surface scans were performed by passing the probes slowly over the surface; the distance between the probe and the surface was maintained at a nominal distance of approximately 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument.

## Exposure Rate Measurements

Measurements of gamma exposure rates were performed using Eberline PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes. Count rates were converted to exposure rates ($\mu$R/h) by cross-calibrating with a Reuter-Stokes pressurized ion chamber, Model RSS-111.

## Gamma Spectroscopy

Samples were placed in an appropriate container, chosen to reproduce the calibrated counting geometry. Net weights were determined and the samples counted using a high purity germanium detector coupled to a Nuclear Data Model ND-66/MicroVaxII pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

| | |
|---|---|
| U-238 | 0.093 MeV from Th-234* |
| U-235 | 0.143 MeV |

Spectra were reviewed for other identifiable photopeaks at concentrations above those normally encountered in environmental media.

* Secular equilibrium assumed.

### Alpha Spectrometry

Solid samples were homogenized and aliquots were dissolved by pyrosulphate fusion and precipitated by barium sulfate. The barium sulfate precipitate was redissolved and the specific elements of interest were individually separated by liquid-liquid extraction. The radionuclides were then precipitated with a cerium fluoride carrier and counted using surface barrier detectors, alpha spectrometers, and a ND-66 Multichannel Analyzer.

### Gross Alpha and Beta in Water

The water sample was acidified, concentrated and dried in a planchet. The sample was counted in a low-background proportional counter.

### Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report represent the 95% confidence level for those data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net sample count was less than the statistical deviation of the background count, the sample concentration was reported as less than the detection limit of the procedures. Because of variation in background levels, detector efficiencies, and the effects of other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument. Additional uncertainties of $\pm 6$ to 10% associated with laboratory procedures have not been propagated into the data presented in this report.

## Calibration and Quality Assurance

The Environmental Survey and Site Assessment Program conducted the survey and analytical activities according to laboratory and field survey procedures specified in manuals developed specifically for the Oak Ridge Associated Universities. The specific manuals and procedures applicable to this survey were the "Quality Assurance Manual," February 1990, Revision 3; the "Survey Procedures Manual," March 1990, Revision 5; and the "Laboratory Procedures Manual," February 1990, Revision 5.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NIST-traceable standards. The calibration procedures for the portable gamma instruments are performed by comparison with a NIST calibrated pressurized ion chamber.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and EML Quality Assurance Programs.

# APPENDIX C

# GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

## Guidelines for Residual Concentrations of Thorium and Uranium Wastes in Soil

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

| Material | Maximum Concentrations (pCi/g) for Various Options | | | |
|---|---|---|---|---|
| | 1[a] | 2[b] | 3[c] | 4[d] |
| Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium | 10 | 50 | -- | 500 |
| Natural Uranium (U-238 + U-234) with daughters present and in equilibrium | 10 | -- | 40 | 200 |
| Depleted Uranium: | | | | |
| Soluble | 35 | 100 | -- | 1,000 |
| Insoluble | 35 | 300 | -- | 3,000 |
| Enriched Uranium: | | | | |
| Soluble | 30 | 100 | -- | 1,000 |
| Insoluble | 30 | 250 | -- | 2,500 |

[a] Based on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 2 mrad/yr to bone from ingestion and inhalation and 10 $\mu$R/h above background from direct external exposure.

[b] Based on limiting individual doses to 170 mrem/yr.

[c] Based on limiting equivalent exposure to 0.02 working level or less.

[d] Based on limiting individual doses to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.

Option 1 concentrations permit unrestricted use of the property and is the guideline applicable to surface soils. Options 2, 3, and 4 apply to buried wastes and assume that intrusions into the burial sites may occur. Regardless of the concentrations in the buried materials, surface soil must meet the Option 1 concentration guidelines.