ORAU Team **NIOSH Dose Reconstruction Project** Technical Basis Document for the Fernald Environmental Management Project – Introduction	Document Number: ORAUT-TKBS-0017-1 Effective Date: 03/17/2004 Revision No.: 01 Controlled Copy No.:_______ Page 1 of 9
Subject Expert: Terry A. Kuykendall Document Owner Approval: Signature on File Date: 03/16/2004 Terry A. Kuykendall, TBD Team Leader Approval: Signature on File Date: 03/16/2004 Judson L. Kenoyer, Task 3 Manager Concurrence: Signature on File Date: 03/17/2004 Richard E. Toohey, Project Director Approval: Signature on File Date: 03/17/2004 James W. Neton, OCAS Health Science Administrator	Supersedes: Revision No.: 00

TABLE OF CONTENTS

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
Draft	12/29/2003	00-A	New Technical Basis Document for the Department of Energy Fernald Environmental Management Project - Introduction. Initiated by Terry A. Kuykendall.
Draft	01/21/2004	00-B	Incorporates comments from internal and NIOSH review. Initiated by Terry A. Kuykendall.
02/17/2004	02/17/2004	00	First approved issue. Initiated by Terry A. Kuykendall.
03/03/2004	03/03/2004	01-A	Incorporates additional comments provided by OCAS. Initiated by Terry A. Kuykendall.
03/17/2004	03/17/2004	01	Approved issue of Revision 01. Initiated by Terry A. Kuykendall.

ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
DOE	U.S. Department of Energy
EA	exposure area
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
FEMP	Fernald Environmental Management Project
FMPC	Feed Materials Production Center
MTU	metric tons of uranium
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
RMI	Reactive Metals, Inc.
TBD	Technical Basis Document

1.0 INTRODUCTION

The purpose of the Site Profiles is to assist with the evaluation of site-specific data in the dose reconstruction process. Each profile provides the rationale and historic background information required for dose reconstruction related to a particular site that participated in the manufacture or assembly of nuclear weapons or their components.

Technical Basis Documents and Site Profile Documents are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH in the completion of the individual work required for each dose reconstruction.

In this document the word “facility” is used as a general term for an area, building or group of buildings that served a specific purpose at a site. It does not necessarily connote an “atomic weapons employer facility” or a “ Department of Energy facility” as defined in the Energy Employee Occupational Illness Compensation Program Act of 2000 (42 U.S.C. § 7384l (5) and (12)).

This Site Profile provides specific information concerning documentation of historic radiological practices at the DOE Feed Materials Production Center (FMPC), later known as the Fernald Environmental Management Project (FEMP). This profile can be used by dose reconstructors to evaluate internal and external dosimetry data for unmonitored and monitored workers and can serve as a supplement to, or substitute for, individual monitoring data. This document provides a site profile of FMPC that contains technical basis information to be used by the ORAU Team to evaluate the total occupational radiation dose for EEOICPA claimants. It provides information on buildings, operations, site conditions, modes and methods of potential radiological exposure, and inferred best estimates of dose parameters where data are missing or might be inaccurate.

In addition, this document provides supporting technical data to evaluate, with claimant-favorable assumptions, the total Fernald occupational radiation dose that can reasonably be associated with worker exposures. This dose results from exposure to external and internal radiation sources in Fernald buildings, occupationally required diagnostic X-ray examinations, and onsite environmental releases. The discussion includes the doses that workers could have incurred while not monitored as well as doses that could have been missed for other reasons. The information in this Site Profile has been assembled to assist in the evaluation of worker dose from FMPC processes and activities using the methodology in the NIOSH *External Dose Reconstruction Implementation Guidelines* (NIOSH 2002a) and *Internal Dose Reconstruction Implementation Guidelines* (NIOSH 2002b).

This Site Profile consists of this introduction and five additional technical basis documents (TBDs) with supporting tables and attachments. This introduction provides a summary description of the remaining TBD sections, which address site and building descriptions (with focus on locations and forms of radiological materials), occupational medical dose, occupational environmental dose, occupational internal dose, and occupational external dose.

Part 2, Site Description, describes the buildings and processes that have been used at the Fernald site for the manufacture and development of nuclear materials. It includes discussion of remediation activities after the cessation of operations.

FMPC operations played an important role in the U.S. nuclear weapons program and were instrumental in the nuclear materials production process. The processes conducted at FMPC included nuclear material processing and machining, fuel fabrication, radiochemical processing, and waste management.

During the Cold War, the Fernald site produced high-purity uranium metal products for the Nation's weapons production program. The site's history began in 1951, when the AEC awarded a $113 million contract to the George A. Fuller Company of New York to construct a uranium processing plant on a 1,050-acre parcel of land 18 miles from Cincinnati, Ohio. The AEC also contracted the Catalytic Construction Company as the architectural and engineering design firm for the site.

Fernald had a primary mission to produce high-purity uranium metal products in the form of ingots, derbies, billets, and fuel cores for other sites in the nuclear weapons complex. Some sites used the products as fuel for nuclear reactors to produce plutonium. The Fernald site was a uranium processing facility; it did not contain a nuclear reactor, nor did it produce or handle explosive devices, nuclear weapons, or highly radioactive material.

The AEC awarded a prime contract in 1951 to National Lead of Ohio (NLO), a wholly owned subsidiary of National Lead Company, to manage and operate the site. In 1986, DOE awarded the management contract to Westinghouse Material Company of Ohio, a subsidiary of Westinghouse Electric Corporation.

Five months after the May 1951 groundbreaking, NLO initiated operations on a plant-by-plant basis. As construction of each production plant was completed, NLO tested the processes and started operations. In October 1951, the Pilot Plant became the first production plant to operate; all plants were fully operational by 1954. By the time construction was complete, 19 acres of the 136-acre production area were under roof, 4 miles of railroad tracks were installed, and 24 acres of paved roads and storage areas were constructed, equivalent to a 20-mile stretch of highway.

During its 38 years of operations, the Fernald site played a critical role in the nuclear weapons complex, delivering nearly 170,000 metric tons of uranium (MTU) metal products and 35,000 MTU of intermediate compounds, such as uranium trioxide and uranium tetrafluoride. From the mid-1950s to the early 1960s, metal production peaked at nearly 12,000 tons a year. Many of the production plants were enlarged in the mid-1950s as part of a site-wide plant expansion effort. In 1975, the site production rate dropped to approximately 900 tons of metal. Production picked up again in the 1980s, but by 1989 demand for uranium feed material was low due to the cessation of the Cold War. This decrease in demand, coupled with an increase in environmental compliance and waste management issues, led to the site management decision to shut down plant operations. In 1991, Congress approved the final closure of site production operations and authorized an environmental remediation mission. To reflect this new mission, DOE changed the name of the site to the Fernald Environmental Management Project.

The 1,050-acre operation was designed as a large-scale, integrated site capable of converting uranium ore and recycled material into uranium metal through a series of chemical and metallurgical conversions. The actual production processes used about 136 acres in the center of the site; the remainder included administration buildings, laboratories, waste storage areas, and buffer zones. The production area contained nine primary plants, each with a specific function in the uranium metal production process.

The first step in the production process was the purification of uranium. In the early years, the site processed uranium ore, including pitchblende from the Belgian Congo, through a series of chemical processes. In later periods, Fernald extracted uranium from scrap metal or recycled material (i.e., floor sweepings, dust collector and production residues) received from onsite operations and other nuclear weapons sites.

Incoming material was weighed, sampled, dried, ground, and classified in Plant 1, then drummed and transported to Plants 2 and 3 where the material was converted to uranium trioxide. First, the material was dissolved in nitric acid to produce a crude uranyl nitrate solution for solvent extraction purification. Purified uranyl nitrate was concentrated by evaporation and thermally denitrated to uranium trioxide, called *orange oxide*. The orange oxide was either shipped to the gaseous diffusion plant in Paducah, Kentucky, or transported to Plant 4, where it was converted to uranium tetrafluoride, called *green salt*, for reduction to metal.

As an intermediate step, uranium trioxide was converted to uranium dioxide, called *brown oxide*, by reducing it with hydrogen. The brown oxide was reacted with anhydrous hydrogen fluoride to produce green salt. Fernald also produced green salt from uranium hexafluoride received from other sites in the nuclear weapons complex.

The green salt was packaged in 10-gallon cans and transported to the metal production operations in Plant 5, where it was blended with magnesium metal granules, placed in a closed reduction pot, and heated until the contents reacted, producing a uranium mass called a *derby*. The product, which resembled the top of a man's derby hat, weighed up to 370 pounds.

Fernald shipped some derbies to other DOE sites but most were remelted in a vacuum induction furnace and poured into preheated graphite molds to form ingots. Ingots varied in weight, size, and shape and weighed up to 1,400 pounds. Fernald sent ingots to Reactive Metals, Inc. (RMI) in Ashtabula, Ohio, where most were extruded and sent back to the Fernald site for heat treatment and final machining to target element cores for the Savannah River Plant in South Carolina. Enriched uranium ingots were prepared by RMI to produce a billet for direct shipment to the Hanford Site in Washington. In Plant 6, ingots were cut to various lengths and then machined to very tight specifications for the Savannah River Plant.

The Fernald site served as the thorium repository for DOE, and maintained long-term storage areas for a variety of thorium materials. On several occasions from 1954 through 1975, the site produced small amounts of thorium in Plant 8, Plant 9, and the Pilot Plant.

Throughout the production years, products from the Fernald site were used at many different sites in the nuclear weapons complex. From 1952 through 1976, depleted, normal, and enriched uranium cores and fuel core elements were fabricated for the Hanford and Savannah River Sites. From 1976 until 1989, the main products were depleted uranium fuel elements for the Savannah River Plant, enriched extrusion ingots and billets for Hanford, derbies for the Oak Ridge Reservation in Tennessee and the Rocky Flats Plant in Colorado, and slab billets for the Rocky Flats Plant.

In July 1989, Fernald site management shut down uranium metal production to focus on environmental compliance and waste management issues. Later that year, the U.S. Environmental Protection Agency added Fernald to its National Priorities List of Federal Facilities that required remediation. Since that time, the Fernald workforce has been dedicated to cleanup, waste management, and restoration of the site.

Part 3, Occupational Medical Dose, provides information about the dose that individual workers received from X-ray examinations that were required as a condition of employment. These X-rays included preemployment and annual chest X-rays during physical exams.

Part 4, Occupational Environmental Dose, discusses the dose workers received when working outside the buildings on the site from inhalation of radioactive materials in the air, direct radiation from plumes, contact with particles on the skin, and from direct exposure to radionuclides in the soil. The occupational environmental dose includes the dose received by individuals working in radioactive waste areas or administration areas inside or outside the fenced production areas. The primary radiation exposure pathways are inhalation of airborne radionuclides, exposure to direct radiation from materials in the process plants and radioactive waste storage areas.

Due to the various locations of radiation sources at FMPC, the dose received by the worker is highly dependent on the amount of time spent in specific work areas. For dose reconstruction, the FMPC Occupational Environmental Dose TBD has divided FMPC into 11 smaller areas, designated as Exposure Areas (EAs), on a grid that provides a realistic estimated representation of radiological conditions where claimants might have worked.

The technical basis for occupational environmental internal dose is presented as airborne radionuclide concentrations and annual uptakes of individuals, and direct radiation exposure is provided as annual exposure to ambient radiation in millirad in each EA and for each operating year (1951 to 2001).

From 1951 through 1988, the FMPC production years, airborne radionuclide concentrations were derived from routine emissions from operations, including handling and storage of radioactive wastes. From 1989 on, after the end of uranium production, emission quantities from specific remediation and decommissioning activities are not readily available. The resulting radionuclide concentration was derived using environmental air monitoring data from the annual site environmental reports.

Direct radiation dose is the result of photon radiation (i.e., gamma and X-rays) emitted from radionuclides stored on the site. The ambient direct radiation field at FMPC was developed primarily from the waste stored in the K-65 Silos and the materials handled in the radioactive waste pit area.

Part 5, Occupational Internal Dose, discusses the internal dosimetry program at the Fernald site. Internal doses were highly dependent on specific plants and operations and are best discussed on a location-specific basis, as in the following paragraphs. Each process involved some releases that could have resulted in uptakes and internal dose.

There were ten buildings, or plants, at the FMPC, each of which had specific internal dosimetry issues. Internal dose potential existed in the Pilot Plant throughout the history of the site as a result of continuing processes with a variety of uranium compounds. In addition, 70% of the thorium production at the site was performed in the Pilot Plant. Plant 1 was designated as the official AEC sampling station for determining uranium and isotopic assays of uranium ores and concentrates; internal dose exposure potential resulted from releases from equipment and during handling. Plants 2 and 3 conducted the chemical processing of ores and residues, and involved large quantities of uranium and its daughter products in liquid and solid forms that resulted in the release of significant quantities of uranium compounds to the work environment. Plant 4 conducted a chemical conversion process that resulted in measurable levels of activity of in-process uranium compounds in the air in the work environment. Plant 5 metal handling processes were inherently dusty and produced air contamination. Plant 6 fabrication activities produced internal exposure potentials of significance through relatively frequent uranium fires and handling operations. Plant 7 handled UF_6 for three years, which is volatile and inherently difficult to contain, and produced significant releases. Plant 8 processed large quantities of uranium and thorium with resultant releases. Plant 9 provided fabrication of uranium and thorium metal parts, and the internal exposure potential was consistent with the other FMPC plants performing similar operations.

Each plant had waste or scrap products that it stored or processed for reuse or disposal in areas called Production Area Waste Sites. Each of these operations had relatively high (with respect to other FMPC operations) internal exposure potential.

Other waste sites include the K-65 storage silos and the disposal pits that were constructed for radioactive waste products from plant processes. Internal exposure potential exists for disposal operation personnel and results from materials in the silos and wind-borne waste materials from the pits.

In addition, Part 5 addresses the issue of potential missed internal dose and discusses the changing radiation detection techniques and equipment at Fernald during the period of interest.

Part 6, Occupational External Dose, discusses the program for measuring skin and whole-body doses to the workers from radiation sources outside the body. The methods for evaluating external doses to workers have also evolved over the years as new techniques and equipment have been developed. In addition, concepts in radiation protection have changed. As in the internal dose discussion, this Part describes the potential for missed external dose.

Occupational external radiation exposure occurred at every manufacturing and waste storage building on the FMPC site. The major contributors to external dose were plants that contained large inventories of raw materials, finished products, or wastes and the radioactive elements in those materials. The products were uranium metals, some containing technetium when recycled uranium was introduced. Thorium also was handled and stored at FMPC. The wastes included those generated by the production processes along with radium from materials stored in concrete silos.

Considering the amounts of materials processed and the relatively small number of production workers, it seems likely that few workers routinely exceeded established exposure limits. However, many workers might have approached these exposure limits. Early dosimetry programs complied with the precedents established by the Oak Ridge Reservation, and used Oak Ridge dosimeters until FMPC converted to a commercial DOE-accredited system. By that time the FMPC mission had changed; for all practical purposes, production had ceased and planning for the retirement of plants had started. Since that time, worker exposures have been well within established limits.

References

NIOSH (National Institute for Occupational Safety and Health), 2002a, *External Dose Reconstruction Implementation Guidelines*, Revision 1, OCAS-IG-001, Office of Compensation Analysis and Support, Cincinnati, Ohio.

NIOSH (National Institute for Occupational Safety and Health), 2002b, *Internal Dose Reconstruction Implementation Guidelines*, OCAS-IG-002, Office of Compensation Analysis and Support, Cincinnati, Ohio.