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# FEED MATERIALS PRODUCTION CENTER ANNUAL ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1989

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REPORT

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FMPC-2200
Special UC-707
October 1990

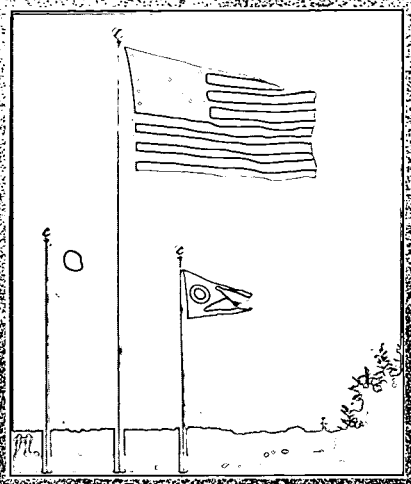
# FEED MATERIALS PRODUCTION CENTER

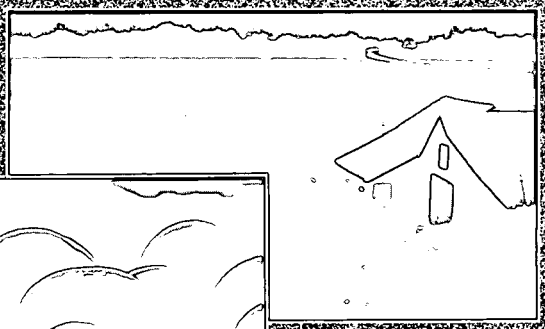
# Annual Environmental Report for Calendar Year 1989

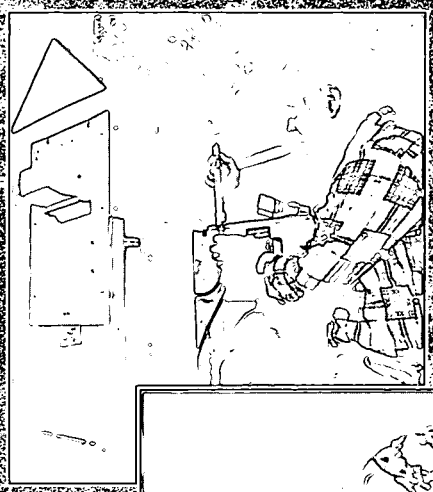
by
Environmental Management Department
Westinghouse Materials Company of Ohio

prepared for
U.S. Department of Energy
Oak Ridge Operations Office

Under Contract DE-AC05-86OR21600







FMPC-2200
Special
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# Feed Materials Production Center Annual Environmental Report for Calendar Year 1989

by
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**October 1990**

Prepared for:

**U. S. Department of Energy**
**Oak Ridge Operations Office**

Contract DE-AC05-86OR21600

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## ACRONYMS

| | |
|---|---|
| AHF | Anhydrous Hydrogen Fluoride |
| AMS | Air Monitoring Station |
| ANSI | American National Standards Institute |
| BAT | Best Available Technology |
| BDN | Biodenitrification Facility |
| $BOD_5$ | Five-Day Biochemical Oxygen Demand |
| BMP | Best Management Practices |
| BSL | Biodenitrification Surge Lagoon |
| BTU | British Thermal Units |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| DOE | Department of Energy |
| EA | Environmental Assessment |
| EDL | Economic Discard Limit |
| EE/CA | Engineering Evaluation/Cost Analysis |
| EIS | Environmental Impact Statement |
| EML | Environmental Measurements Laboratory |
| EMR | Environmental Monitoring Report |
| FFCA | Federal Facility Compliance Agreement |
| FMPC | Feed Materials Production Center |
| FS | Feasibility Study |
| ICRP | International Commission on Radiological Protection |
| NAAQS | National Ambient Air Quality Standards |
| NCRP | National Council on Radiation Protection and Measurements |
| NEPA | National Environmental Policy Act |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NPDES | National Pollutant Discharge Elimination System |

## ACRONYMS (CONTINUED)

| | |
|---|---|
| NRC | Nuclear Regulatory Commission |
| OAC | Ohio Administrative Code |
| ODH | Ohio Department of Health |
| OEPA | Ohio Environmental Protection Agency |
| ORNL | Oak Ridge National Laboratory |
| ORO | Oak Ridge Operations |
| PCB | Polychlorinated Biphenyls |
| PET | Proficiency Environmental Testing |
| PTI | Permit to Install |
| PTO | Permit to Operate |
| QA | Quality Assurance |
| QF | Quality Factor |
| RCRA | Resource Conservation and Recovery Act |
| RI/FS | Remedial Investigation and Feasibility Study |
| RI | Remedial Investigation |
| SSLS | Storm Sewer Lift Station |
| SWOAPCA | Southwestern Ohio Air Pollution Control Agency |
| SWRB | Stormwater Retention Basin |
| TLD | Thermoluminescent Dosimeter |
| TSCA | Toxic Substances Control Act |
| TSS | Total Suspended Solids |
| USEPA | U. S. Environmental Protection Agency |

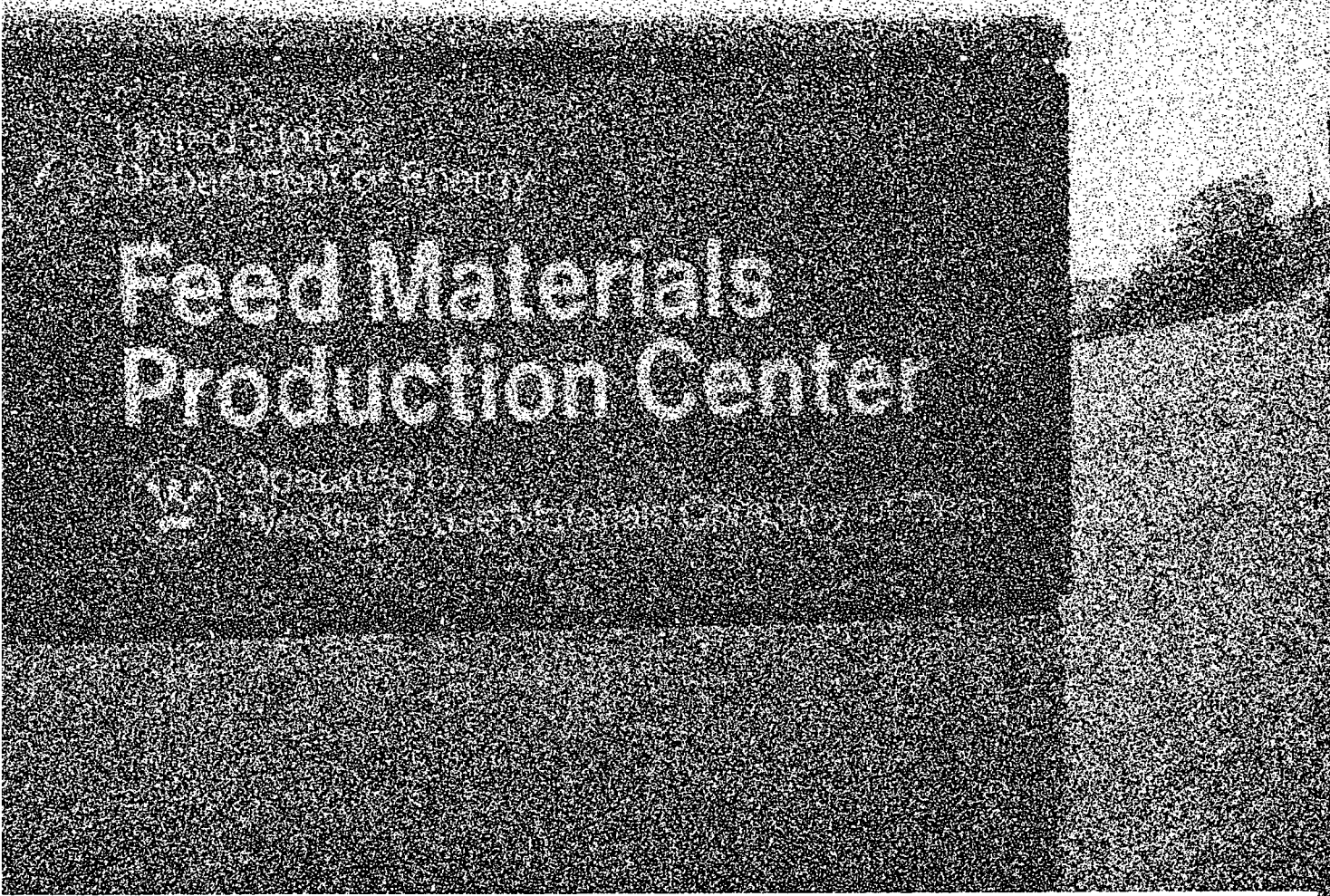
## CONVERSION TABLE

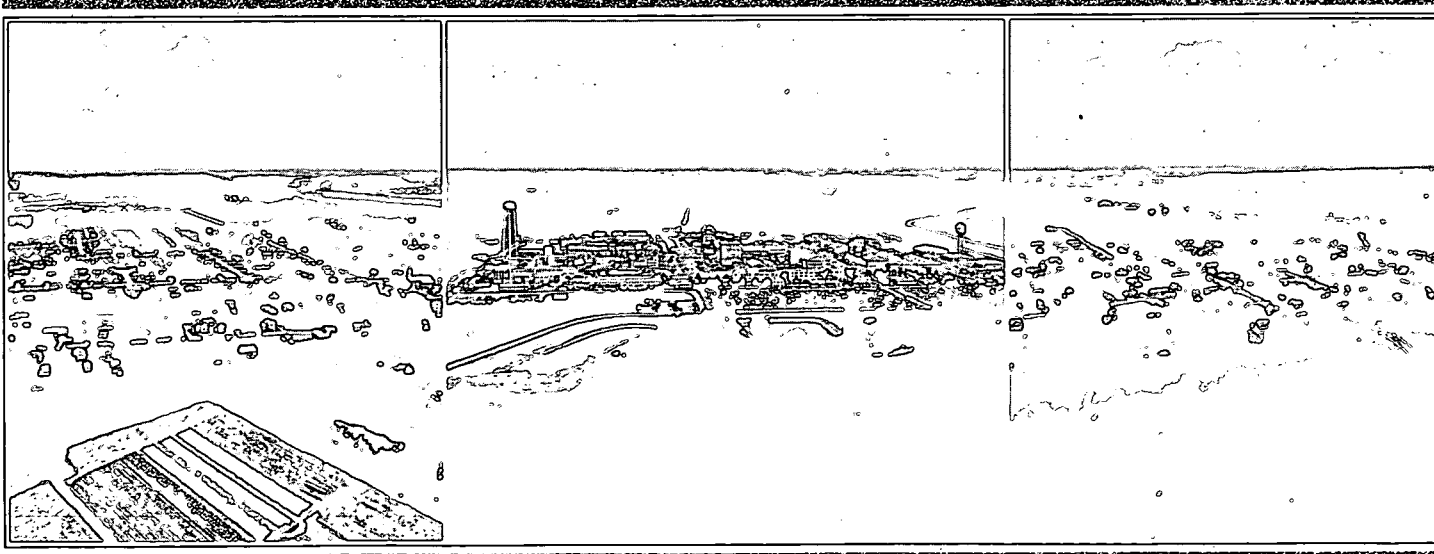
Traditional radiological units (curie, roentgen, rad and rem) are used throughout this report. Wherever possible, the more scientifically acceptable Systeme Internationale (S.I.) units (becquerel and sievert) are also presented in parentheses. The metric system of units of measurement is the primary system used for nonradiological parameters. The English system equivalent units are frequently presented in parentheses.

To facilitate conversion of data from one system to another, this table may be useful.

| Equivalent Units | |
|---|---|
| 1 centimeter | 0.3937 inch |
| 1 meter | 39.37 inches |
| 1 kilometer | 0.62 mile |
| 1 milliliter | 0.0338 fluid ounce<br>0.061 cubic inch |
| 1 liter | 1.057 quart<br>61.02 cubic inches |
| 1 gram | 0.0353 ounce<br>0.0022 pound |
| 1 kilogram | 2.2 pounds |
| 1 curie | $3.7 \times 10^{10}$ disintegrations/second<br>$2.22 \times 10^{12}$ disintegrations/minute |
| 1 becquerel | 1 disintegration/second<br>27 picocuries |
| 1 millicurie | 0.001 curie |
| 1 microcurie | 0.000001 curie |
| 1 picocurie | $1 \times 10^{-12}$ curie<br>2.22 disintegrations/minute<br>0.037 bequerel |
| 1 roentgen | $2.58 \times 10^{-4}$ coulombs/kilogram of air |
| 1 rad | 0.01 gray |
| 1 rem | 0.01 sievert |
| 1 millirem | 0.001 rem |
| **The following apply to natural uranium in water** | |
| 1 µgU/l | 1 part per billion (ppb)<br>0.68 pCi/l |
| 1 mgU/l | 1 part per million (ppm)<br>680 pCi/l |

# Executive Summary and Environmental Compliance Self-Assessment



# Executive Summary and Environmental Compliance Self-Assessment

The mission of the Department of Energy's (DOE) Feed Materials Production Center (FMPC) has been to process uranium for United States' defense programs. On July 10, 1989, the FMPC suspended production operations, but remains on standby for certain segments of production. The FMPC also manages the storage of some radioactive and hazardous materials.

As a part of its operations, the FMPC continuously monitors the environment to determine that it is operating within federal and state standards and guidelines regarding emission of radioactive and nonradioactive materials.

Data collected from the FMPC monitoring program are used to calculate estimates of radiation dose for residents due to FMPC operations. For 1989, the estimate of dose through the air pathway, excluding radon, indicated that people in the area were exposed to less than 6% of the DOE guideline established to protect the public from radiation exposure. When radon emissions are included, the dose from FMPC operations during 1989 was less than 22% of the annual background radiation dose in the Greater Cincinnati area.

This report is a summary of FMPC's environmental activities and monitoring program for 1989. An Environmental Compliance Self-Assessment, which begins on page xxiii, presents the FMPC's efforts to comply with environmental regulations through June 1990.

## Scope of this Report

The scope of the Environmental Monitoring Report (EMR) is wide ranging. It describes the ways in which emissions from the site can reach the surrounding environment, presents the various sampling programs in place such as air, soil, and groundwater, and includes the monitoring data collected during 1989. In addition, the report explains how these data are used with information about the site and

nearby communities in order to estimate the maximum doses an individual and the general public could receive from activities at the site. Information is also provided on quality assurance practices, waste management activities at the site, and work being performed to address the effects of past operations.

## Following Environmental Standards

Because it is not possible to prevent entirely the release of all radioactive and nonradioactive materials from any manufacturing or production facility, the United States Environmental Protection Agency (USEPA), the Ohio Environmental Protection Agency (OEPA), and the DOE establish standards and guidelines for emission levels that are designed to ensure public health and safety. These standards are based upon recommendations by the National Council on Radiation Protection and Measurements (NCRP), the USEPA, the International Commission on Radiological Protection (ICRP), other scientific bodies, and government agencies. Standards have not yet been established for all pollutants. In those instances, the FMPC compares the 1989 sampling results with comparable data from previous years, with control data from samples taken at areas unaffected by FMPC activities, and with published data for the concentrations of substances normally present in nature.

## Estimated Radiation Doses to the Public

Each year, the FMPC estimates the radiation doses generated by operations at the site. The largest overall potential source of radiation exposure to the public from the operation of the FMPC is through the air. This pathway will provide, for a specific radionuclide, the greatest dose to a population or to a specific population group. Chapter Two describes some fundamental information on radiation, including definitions for terms used in dose estimates. Chapter Four presents the methods and results of the dose estimates.

As previously stated, the estimate of dose due to FMPC operations, excluding radon, during 1989 indicated that people in the

surrounding area were exposed to a maximum committed effective dose of 1.2 mrem which was less than 2% of the DOE guideline, and an organ dose that was less than 13% of the 1989 National Emission Standards for Hazardous Air Pollutants (NESHAP) standard for organ dose. These are very conservative estimates because, to receive those doses, residents would have to remain outside their homes 100% of the time for an entire year. These dose estimates take into account airborne emissions, population distribution, and meteorological data. Higher values were obtained for the above doses when estimates of airborne emissions from the waste pits were included in the AIRDOS-EPA calculations. However, as discussed in detail in Chapter Four, "Estimated Radiation Doses for 1989," the quantities of airborne radionuclides emitted from the pits were grossly overestimated resulting in erroneously high dose estimates which do not reflect the actual exposures resulting from FMPC operations.

The FMPC also calculated doses the public could receive from the liquid pathway, the indirect pathways of eating produce or fish from the surrounding area, and from external radiation and radon which are produced by materials stored at the site.

The FMPC was able to estimate radon concentration at the fenceline because the precision of the data has improved over previous years. The radon concentration above-background, 0.24 $\pm$ 0.15 pCi/l, was a fraction of the average indoor radon concentration recently reported for homes in the Cincinnati area (more than 50% of the 2,951 homes studied had levels of radon exceeding 2 pCi/l). To calculate the dose from radon emissions, it was assumed that a person breathed air containing 0.24 pCi/l of radon continuously for an entire year. This would result in a maximum effective dose of 72 millirem.

These doses can be compared to the average radiation dose of 360 mrem that each U. S. resident is exposed to every year. About 300 mrem come from radon and other natural sources. Other contributors include medical X-rays and household items like televisions.

The effective dose due to natural background radiation for the entire population within 80 km (50 miles) of the FMPC was 950,000 person-rem. The committed effective dose due to 1989 airborne

emissions from the FMPC was 21 person-rem for the same population group.

# Environmental Monitoring Results

To obtain the data for the dose calculations, and to estimate the impact of FMPC operations on the health and safety of nearby residents, the FMPC continued its ongoing program to monitor the environment. Chapter Three of this report details the monitoring program.

## *The Air Pathway*

The average concentrations of uranium at the 14 air monitoring stations located along the FMPC boundary and offsite were all less than 1% of the DOE guideline and were well below last year's average. Uranium emissions to the air totaled 30.1 kg (66 pounds) for 1989.

No directly applicable standards exist for uranium concentrations in soil or in grass. The FMPC compared soil data collected during 1989 to published values for naturally-occurring uranium for Ohio soils. Eleven of the 21 offsite samples were above this background range for Ohio soils including a control sample from Westwood, Ohio, which is 24 km (15 miles) from the site. In general, uranium concentrations in grass near the FMPC were no different than the concentrations found some distance from the site.

The FMPC sampled produce from 13 farms and gardens within 3.2 km (2 miles) of the site, and also, as a control measure, from six farms located between 16 and 48 km (10 to 30 miles) from the site. The data indicate that the uranium concentration in produce grown near the site did not differ from the concentration in produce grown at the control locations.

The FMPC collected monthly samples of milk from the dairy located next to the site and from a control dairy located about 35 km (22 miles) west of the FMPC. The average uranium concentrations present in the milk samples from both locations were below the laboratory's minimum detectable level for every month except October. However, the positive October results for both the

adjacent and control dairies are considered incorrect and most likely were caused by contamination or problems at the contractor laboratory where the samples were analyzed. This is discussed in Chapter Three.

## The Liquid Pathway

The FMPC carefully monitors the liquid pathway to determine if radioactive and nonradioactive materials from the site are entering the surrounding environment. The FMPC's groundwater monitoring program has grown significantly during the last year with the addition of monitoring wells both on the FMPC site and, with the cooperation of FMPC neighbors, in the immediate vicinity of the site.

The groundwater data indicated that uranium concentrations for the 13 onsite wells that are part of the Environmental Monitoring Program were significantly below the DOE drinking water guideline. Thirty offsite wells were sampled during 1989 for the Environmental Monitoring Program. Three of these wells were identified several years ago as contaminated; they are being addressed under the CERCLA remediation process. The other 27 wells had uranium concentrations considerably below the proposed guideline and were in the background range for groundwater in this area.

The total amount of uranium in the FMPC effluent to the Great Miami River during 1989 was 841 kg (1,854 pounds). The average uranium concentration at the sampling locations in the Great Miami River downstream of the effluent discharge line was less than 0.3% of the DOE guideline. For 1989, the sum of the percent of guideline of each radionuclide in the liquid effluent discharged to the river was greater than 100% of the DOE guideline. The FMPC is designing an advanced wastewater treatment facility using best available technology to address the situation.

Stormwater runoff from the production area, administration area, and the parking lot are collected in the Stormwater Retention Basin (SWRB). There were two overflows of the SWRB in 1989; about 2.3 million liters (600,000 gallons) of stormwater, which contained 1.0 kg (2.2 pounds) of uranium, were discharged into the outfall ditch. This was a significant decrease in the amount of uranium

discharged into the outfall ditch from years before the SWRB was in operation. Under normal conditions, the water in the SWRB was pumped to the effluent discharge line where it was sampled before it was discharged into the Great Miami River.

Some stormwater does drain from the waste pit area into Paddy's Run along the western boundary of the site. There, the highest average uranium concentration found in Paddy's Run was 13% of the DOE guideline.

The average concentrations for nitrate-nitrogen and fluoride sampled at all surface water locations were less than OEPA standards, as they have been for several years. Average concentrations were the same both upstream and downstream of the FMPC effluent discharge line.

The FMPC met the discharge limits for National Pollutant Discharge Elimination System (NPDES) parameters more than 98% of the time in 1989. Future plans include improving the overall wastewater treatment system at the site to reduce stress on the Sewage Treatment Plant and to continue to improve the NPDES compliance rate.

Uranium concentrations in some sediment samples taken from the outfall ditch near the SWRB were above the background range for Ohio soils. However, sediment samples from the Great Miami River and Paddy's Run, including samples downstream of the outfall ditch, were within the natural-background range.

The uranium concentrations in fish sampled in 1989 were lower than in 1988. The maximum committed effective dose from eating fish from the Great Miami River near the FMPC effluent discharge line would be only 0.03% of the DOE guideline.

## Direct Radiation

The FMPC calculated a dose for exposure to gamma radiation using thermoluminescent dosimeters located at each air monitoring station. The maximum annual gamma exposure of 17 μR/hr (17 μrem/hr) was measured at AMS-6, the station closest to the K-65 Silos on the west side of the site.

In addition, the FMPC used a pressurized ionization chamber to measure direct radiation at several locations near the site.

The estimated annual external gamma dose to the resident living closest to the K-65 Silos was 12 mrem (0.12 mSv) above background, which is 12% of the DOE guideline. Again, this dose included the conservative assumption that the resident remained outside his or her home 100% of the time during 1989.

# Other Environmental Activities

Through the comprehensive Remedial Investigation and Feasibility Study (RI/FS), the FMPC is investigating the nature and extent of potential environmental impacts from past operations at the site. Based upon the results of this investigation, the RI/FS will then develop and evaluate engineering alternatives to mitigate the identified environmental concerns. The study is being conducted for DOE in cooperation with USEPA and OEPA. Work continues on the task of stabilizing the K-65 Silos, which contain waste residues that emit radon. Several options for controlling the radon emissions are being evaluated.

The FMPC successfully completed the second of three projects designed to repackage the thorium stored onsite. All thorium has been removed from an elevated silo and several bins, packaged in special drums as necessary, inventoried, and stored in warehouses onsite. In addition, all thorium stored outside in drums is now stored indoors. These measures have greatly reduced the possibility of thorium being released to the environment.

Improvement projects at the FMPC included upgrading the Biodenitrification Surge Lagoon, upgrading the effluent sampling and monitoring capabilities, and repairing some of the onsite monitoring wells. These projects enable the FMPC to better monitor and protect the groundwater and area surface water from pollutants originating from the FMPC.

The FMPC removed its inventory of uranium hexafluoride, magnesium, anhydrous ammonia, and some miscellaneous chemicals from the site, thus eliminating a significant risk at the FMPC. In addition, several new chemical storage facilities using the best available technology have been built to store remaining chemicals. Even though production was suspended in 1989, shipments of FMPC waste to an offsite storage facility continued.

# Unusual Events

During 1989, two events involving possible airborne uranium releases occurred for which offsite exposures were estimated. The first was a uranium fire on the southeast storage pad of Plant 6 on June 1, 1989. The fire lasted about one-half hour and caused no injuries and little damage. A release of 0.38 kg (0.84 pounds) of uranium was assumed for making dose estimates. The 50-year committed effective dose for the maximally-exposed individual for the fire was 0.069 mrem.

The second unusual event modeled for offsite exposure calculations was a spill of solid material in the gravel area south of Plant 7. Analysis of the material indicated a uranium concentration of 1.0%. Calculations estimate the potential release to be 0.002 kg (0.004 pounds) of uranium. The 50-year committed effective dose for the maximally-exposed individual for the spill was 0.0001 mrem.

# Environmental Compliance Self-Assessment

The FMPC must comply with environmental requirements established by a number of federal and state statutes and regulations, Executive Orders, DOE Orders, and various regulatory compliance agreements. In the summer of 1989, production activities at the FMPC were temporarily suspended. The major emphasis at the facility is now on cleanup, remediation, and restoration activities. Compliance with major environmental statutes and agreements for 1989 through June 1990 is summarized below.

### Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

In 1986, DOE and the USEPA entered into the Federal Facilities Compliance Agreement (FFCA) in which DOE agreed to comply with various federal and state pollution control regulations including those that implement the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The FFCA addresses the remediation of inactive waste sites and waste storage areas. Since this agreement was concluded, the FMPC has been actively working to ensure that all FFCA actions, including those for CERCLA compliance, are achieved. The FMPC was successful in meeting CERCLA deliverables during 1989.

Effective December 1989, the FMPC was placed on the USEPA's National Priorities List (NPL) of sites requiring environmental cleanup action under CERCLA. Thereupon, DOE and the USEPA began developing a statement of the CERCLA actions required at the FMPC. This statement became the "CERCLA 120 Consent Agreement" which was signed by the DOE and the USEPA in April 1990, and was effective June 1990.

Anticipating the new CERCLA agreement, FMPC began developing a CERCLA Implementation Plan. The Implementation Plan, which is now being refined, is expected to be an effective vehicle for managing the multitude of actions required under the "CERCLA 120 Consent Agreement." The FMPC also established a CERCLA

Working Group to assist in identifying and resolving special CERCLA issues.

### Clean Air Act (CAA)

In Ohio, authority to enforce requirements of the Clean Air Act (CAA) has been delegated by the USEPA to the Ohio Environmental Protection Agency (OEPA), except for the enforcement of the radionuclide National Emission Standards for Hazardous Air Pollutants (NESHAP). Because most of the FMPC's air emission sources potentially can emit both radioactive and nonradioactive particulates, operation of most FMPC sources requires the approval of both regulating agencies.

The FMPC must meet NESHAP standards and obtain NESHAP approvals for new radionuclide sources as required by 40 CFR 61, Subpart H. In 1989, the FMPC met the standard of 25 mrem/year or less effective dose equivalent exposure to the maximally-exposed resident from airborne radionuclides.

Although FMPC production activities were discontinued in mid-1989, the FMPC must obtain Ohio Permits To Install (PTIs) and Permits To Operate (PTOs) for air emission sources. The application for these permits must contain information on radionuclide and nonradioactive emissions from each particular source and must be filed with the Southwest Ohio Air Pollution Control Agency (SWOAPCA) for ultimate approval by OEPA. The FMPC currently has 143 active permits with an additional 86 permits in the renewal process and 33 new permit applications pending. The FMPC has identified over 400 possible emission sources, either from operable equipment or equipment with no apparent future need. Efforts are ongoing to ensure that all emission sources are permitted.

### Clean Water Act (CWA)

As part of the Clean Water Act (CWA), the FMPC is permitted under the National Pollution Discharge Elimination System (NPDES) by the State of Ohio and must control the discharge of nonradiological pollutants to Ohio waters. The permit specifies discharge and sampling locations, sampling and report schedules, discharge limitations, water quality standards, and other discharge restrictions. There were seven regulated discharge locations in 1989: two discharges were directly to Ohio waters and five were

internal contributing waste water streams. Liquid effluents collected at the NPDES sampling points during 1989 indicated that the FMPC met the NPDES daily maximum and monthly average permit limits more than 98% of the time. Through reduced operations, facility improvements, improved procedures and practices, and responsible management of wastewater programs, significant improvements were made in NPDES noncompliances during 1989 (110 non-compliances in 1988 versus 24 in 1989). Only one noncompliance occurred during the last six months of 1989. Details of NPDES noncompliances are provided in Chapter Three, "Results of the FMPC Environmental Program."

### Resource Conservation and Recovery Act (RCRA)

The FMPC generates both RCRA hazardous wastes and mixed waste (hazardous wastes mixed with radionuclides). The hazardous wastes are accumulated at satellite accumulation areas throughout the facility and then are stored in designated RCRA storage facilities until they can be shipped offsite to a RCRA permitted treatment or disposal facility. Mixed waste must be stored onsite as there are no facilities currently available for its treatment or disposal.

The FMPC facility is pursuing a hazardous waste storage permit under RCRA. An extensive revision of the FMPC's RCRA Part B Application was completed and submitted to OEPA on September 22, 1989, along with an updated Part A Application. These applications were submitted unsigned due to liability questions in regard to federal facility management. Consent Decree amendments currently being negotiated with the State of Ohio will provide a schedule for submission of properly executed Part A and Part B Applications.

As part of the RCRA Part B Application, all mixed waste streams must be fully characterized. Through negotiations with the State of Ohio, schedules were established to complete all characterization work, including the drums of waste stored in warehouses and on Plant 1 pad. Process-knowledge evaluations on all containers of thorium materials should be completed and a schedule for analyzing and overpacking these materials developed by February 1991. Characterization of remaining FMPC wastes stored in containers is to be completed by September 1992. Efforts have begun to meet these schedules.

USEPA issued a Notice Of Violation (NOV) in December 1989 for several findings from June and August 1989 RCRA inspections. Many of these issues have been resolved. Other issues are being discussed with the USEPA.

### Toxic Substances Control Act (TSCA)

The FMPC stores radioactively-contaminated PCB materials from past operations and maintenance activities in the KC-2 Warehouse and Building #79 in compliance with TSCA requirements. The Notification of Activities form required by revised TSCA regulations was submitted in April 1990, and USEPA has responded by issuing a facility identification number. Annual PCB inventory reports are completed and maintained in files at the FMPC by July 1 of each year. Although no approved disposal source currently exits for this material, the FMPC is exploring various disposal options.

### National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) was enacted to declare a national policy to promote efforts which will prevent or eliminate damage to the environment. DOE Order 5440.1(C), "Implementation of the National Environmental Policy Act," was issued on April 9, 1985. This order required DOE facilities to comply with provisions of NEPA. In October 1988 the DOE NEPA Draft Compliance Guide was issued establishing guidelines for DOE and contractor personnel to implement NEPA regulations. On February 14, 1990, a Secretary of Energy Notice (SEN-15-90) was issued. This notice requires DOE organizational restructuring as to the NEPA approval cycle, revisions to DOE orders and guidelines concerning NEPA, and an expansion of the categorical exclusions list.

The NEPA/CERCLA integration strategy for incorporating NEPA requirements into the site remediation program was developed and implemented in FY-1990. The strategy calls for integrating the EIS/EA level information into the FS documents. Two public scoping meetings for the remediation EIS/EA were held in late June 1990.

### Consent Decrees with the State of Ohio

In December 1988, the DOE consented to the requirements contained in two separate federal district court decrees. Those

decrees arose from various environmental issues. Collectively, those Consent Decrees address issues under RCRA, CWA, and CAA and imposed actions and schedules on the FMPC. Progress on those scheduled actions had been reported to the OEPA bimonthly. In April 1990, the State of Ohio filed contempt of court charges in federal district court alleging violations of one of the consent decrees. Immediately, the DOE and the State of Ohio began negotiating a resolution of those issues. Those negotiations are continuing.

## *Current Accomplishments and Issues*

### CERCLA Accomplishments

Major CERCLA actions completed in 1989 until the present included submittal of an initial report to USEPA screening alternative remedial actions for Operable Unit 4 (the K-65 Silos), submittal of EE/CAs for two removal actions (the South Plume and Waste Pit Runoff Control), and a close-out of the removal action for contaminated soil near Manhole-180. A time-critical removal action was also initiated for perched water under Plant 6. This action was later suspended in April 1990 pending assessment of additional technical issues regarding the complete removal of organics found in the perched water.

Revised CERCLA cleanup standards and criteria were issued in March 1990 as part of the National Oil & Hazardous Substances Contingency Plan (NCP). To meet these new requirements, the FMPC initiated the requirement that Removal Site Evaluations (RSE) be performed prior to any maintenance or construction activity involving the movement of one cubic yard or more of soil. The RSEs will help assess and control the threat of releases of hazardous substances during such activities. An Administrative Record file, which is open to the public, is being maintained. This file will contain all documents pertinent to the CERCLA decision-making process.

### RCRA Accomplishments

The FMPC site-wide RCRA Implementation Program was expanded in early 1990. The expanded effort consists of 31 Implementation Tasks, 26 of which are targeted for completion no later than the end

of CY-1991. Specific Implementation Tasks include many of the areas identified for improvement by USEPA and OEPA. Additional Hazardous Waste Management Units (HWMU) were identified during the period including Underground Storage Tank 5. The FMPC is currently performing a detailed Hazardous Waste Management Unit Review (HWMUR) to assess and fully identify any remaining HWMUs and waste streams at the FMPC.

Major RCRA efforts for CY-1990 include the development of a closure plan for Underground Storage Tank 5; a closure plan for the Plant 1 Pad; a Waste Determination Plan, and a process knowledge assessment of drums which might contain RCRA materials.

### Thorium Management Accomplishments

In late 1987, the FMPC developed a comprehensive three-project plan for improving the temporary storage conditions for the thorium inventory. The first project addressed the bulk thorium materials in the Plant 8 silo and bins. This repacking project was completed in March 1989. The silo and bins were then decontaminated and demolished.

The second project was the overpacking of 50 tons of thorium metal and residue stored outdoors in 240 containers (including 210 drums). A remote system to handle, identify, and overpack the drums and containers was designed. Each container was inventoried, weighed, overpacked, and placed in temporary storage. This project was completed in May 1990.

By completing these two projects, the FMPC has significantly reduced the potential for any release of thorium through a structural failure of a deteriorating container. The third project to overpack warehoused thorium materials is being planned.

### CERCLA/SARA Issues

In the first quarter of CY-1990 drums on the FMPC Plant 1 Pad were found to contain less than their recorded weights indicated. These drums were immediately put into larger drums (overpacked), sealed, and stored indoors. The FMPC reported the possible loss of unlisted hazardous waste to the National Response Center, the OEPA, and the local emergency planning organizations as required under CERCLA/SARA. Actions are underway to identify other

drums that may need to be overpacked and stored indoors as space which meets regulatory requirements becomes available.

### Land Disposal Restricted Waste

The FMPC currently stores liquid low-level radioactive waste that also contains RCRA hazardous waste (known as mixed waste) subject to the Land Disposal Restrictions, which allows storage only for the purpose of accumulating sufficient quantities for treatment. This waste is being stored due to the lack of treatment or disposal facilities for the type of mixed waste. The DOE and USEPA are continuing to discuss the issue, and the inventory of such materials is reported to USEPA on an annual basis. The DOE expects to negotiate a FFCA with USEPA that would detail the steps needed to attain compliance.

### Clean Air Act Issues

New, more stringent NESHAP rules under Subpart Q became effective in March 1990, establishing standards for radon emissions from federal facilities. The FMPC has three above-grade silos which emit radon and are affected by these standards. The CERCLA remedial action being developed for these silos, as part of the RI/FS work at the FMPC, will develop measures addressing the emission of radon from the silos.

In April 1990, the OEPA issued proposed revisions to the State Implementation Plan (SIP) which would require the FMPC to reduce its $SO_2$ emissions by 54%. FMPC filed comments to the proposed revision and is continuing to work with the OEPA on problems FMPC has with the assumptions and other technical aspects of the modeling from which the proposed emission reduction factor was derived for the FMPC.

### Offsite Water-Supply Wells

Prior to 1990, the FMPC had identified three water-supply wells contaminated with uranium. The first land owner was provided with a new deep well as an alternate drinking water source. The next two land owners are the subject of an Engineering Evaluation/Cost Analyses (EE/CA) for removal actions to supply an alternate water source. The FMPC is awaiting approval of the removal action work-plan from the USEPA. In early 1990, the FMPC identified a gradual increase in uranium concentrations at a

fourth property. Bottled water has been supplied while negotiations to provide an alternate water supply continue with the land owner. The total uranium concentrations found in these wells range from 4.6 to 280 ppb.

The FMPC continues to closely monitor groundwater sources as part of its systematic groundwater program.

### Groundwater Monitoring Wells

During the 1980s, about 170 wells were installed in and around the FMPC site to identify and track the movement of contaminants which may be present in the Great Miami Aquifer. Wells extending into the upper portion of the sand and gravel aquifer are denoted as 2000–series, wells placed within the lower portion of the upper sand and gravel aquifer are denoted as 3000–series, and wells installed in the sand and gravel aquifer which underlies another layer of clay are denoted as 4000–series wells. The highest historical concentration of uranium in an onsite sand and gravel well was discovered during 1990 in a 2000–series well, at a concentration of 907 ppb. The highest concentration of uranium in an offsite well during 1990 was 312 ppb, also from a 2000–series well.

In response to the identification of offsite contaminants, a removal action under CERCLA is currently being planned and negotiated with the USEPA This action involves the installation of alternate water supplies for industrial concerns and the installation of recovery wells to halt the advancement of the south plume. In addition, all contaminated environmental media, including ground water, are being addressed under Operable Unit 5 (as defined in CERCLA 120 Consent Agreement).

### Tiger Team Assessment

In August 1989 DOE conducted a comprehensive assessment of environmental, safety, and health practices at the FMPC. The assessment concluded that the FMPC was not in full compliance with all regulatory requirements, agreements, and DOE Orders.

A report on the findings was made available to the regulatory community and the public. Action plans were established at the FMPC to address each of the Tiger Team findings. For the 155 Tiger Team actions, 54 were completed as of June 12, 1990, and 34

items are scheduled to be completed by the end of September 1990. A number of actions remain to be scheduled.

## Environmental Permits

The FMPC must obtain and operate by a number of environmental permits to be in compliance with current environmental statutes. A summary of the environmental permits required and issues surrounding these permits follows.

### National Pollutant Discharge Elimination System (NPDES)

A new NPDES Permit was approved by the OEPA in February 1990. The new permit reflects more stringent discharge requirements (including pH limitations and additional heavy metals) along with adding sampling requirements. Additional monitoring equipment was also recently added at the FMPC. The FMPC facility is expected to maintain a high rate of compliance with the new permit during the remainder of 1990.

### Air Permits

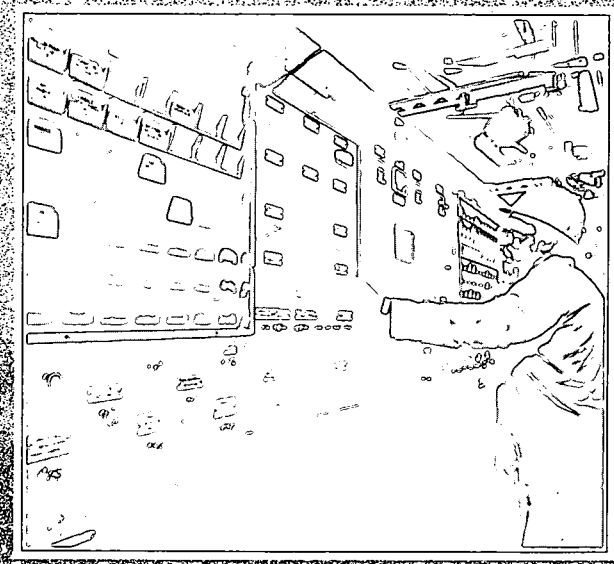
In 1989, the FMPC obtained a total of seven new NESHAP approvals for air emission sources with radionuclides. A total of 13 PTIs and 22 PTOs were also been obtained from OEPA during 1989. Permit applications will continue to be developed as necessary in support of FMPC activities.

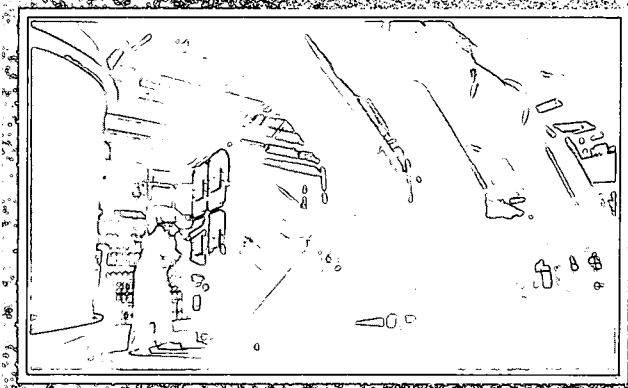
### RCRA Permits

The FMPC's RCRA Part B Application was revised and submitted unsigned to OEPA September 1989. Comments on this application are expected in late 1990. After these comments are received, revised Part A and Part B Permit Applications will be submitted in 1991 with updated HWMU and waste stream characterization information prior to final OEPA approval.

# CHAPTER 1

# Introduction





CHAPTER ONE

# Introduction

In recent years, the Feed Materials Production Center (FMPC) has been expanding its environmental monitoring program and conducting a thorough site-wide investigation of the environmental conditions at the site. Work related to the environment has been given the highest priority. Indeed, the FMPC reached a turning point in its history on July 10, 1989. On that date, production operations were suspended after more than 37 years of manufacturing uranium-metal products for United States' defense programs. The basis for this decision was to allow employees to focus their efforts on environmental programs so the FMPC will be able to comply with federal and state environmental regulations.

## Purpose of the Environmental Monitoring Program

The FMPC engages in a broad range of activities related to environmental monitoring as a way to determine the amount of radioactive and nonradioactive materials that leave the FMPC site and enter the surrounding environment. The year-round Environmental Monitoring Program is designed to:

- Ensure that the FMPC can detect any unusual release of materials as quickly as possible so that corrective actions can be implemented
- Closely monitor releases to ensure that air emission and liquid effluent standards and guidelines are not exceeded
- Estimate the radiation dose that area residents may be exposed to as a result of operations at the site
- Measure progress in correcting problems from past operations and in implementing improved environmental management practices.

This Environmental Monitoring Report (EMR) focuses on the results of the ongoing FMPC Environmental Monitoring Program

and provides general information on the major waste management and environmental restoration activities during 1989. While many environmental investigations have begun recently, the Environmental Monitoring Report for the FMPC has been published since 1960.

The EMR presents information according to requirements stated in DOE Order 5400.1.[1] To help readers understand the material presented in the rest of the report and the structure of the Environmental Monitoring Program, this chapter provides background information on the following topics:

- The changing mission at the FMPC
- Status of production operations
- Physical and ecological characteristics of the FMPC site and surrounding area
- Economic activities in the Fernald area
- An overview of production operations
- Handling and storing radioactive and hazardous materials
- Exposure pathways to humans
- The environmental standards and guidelines with which the FMPC must comply
- History of the FMPC Environmental Monitoring Report.

Within this report, annual summaries of environmental data are presented in the text, as figures (usually as bar charts), and/or in tables. In some instances, the summary tables display the sampling location, number of samples collected, minimum, maximum and average concentrations, and the percent of standard.

# The FMPC Mission: Changing from Production to Restoration

Today's mission at the FMPC, emphasizing environmental compliance and restoration, is quite different from previous years when the FMPC mission was producing uranium metal. Planning for the FMPC began shortly after the end of World War II when the United States government recognized the need for new facilities to produce uranium metal. Existing facilities, developed for the war

effort, were not economical to operate or able to meet increasing demands. The Atomic Energy Commission wanted to increase the quality and quantity of uranium metal production as well as improve control and increase the safety of production operations.

After careful study, the government selected an area just north of Fernald, Ohio as the site for a new production facility (Figure 1). The FMPC is located about 27 km (17 miles) northwest of downtown Cincinnati, Ohio. Ground was broken on May 16, 1951, and the first uranium metal, called a derby, was produced at the FMPC on October 11, 1951. The major portion of construction was completed by 1954.

In general, the relative importance and corresponding funding of the FMPC's production and environmental activities reflect the course of events in the United States from the end of World War II until today. Uranium-metal production reached a peak during the height of the cold war during the 1950s and 1960s. Federal and state waste management requirements were applied, but environmental issues were not the high priority they are today.

Funding for FMPC production and supporting organizations, including environmental monitoring, was significantly reduced during the late 1970s. The site nearly closed. But during the early 1980s, the U.S. increased defense spending and production at the FMPC accelerated. At the same time, there was an increase in the number and stringency of environmental regulations. During the late 1980s, a combination of elements strongly influenced the FMPC to change its mission: the demand for environmental accountability increased dramatically, and some operations were halted at other DOE facilities that used FMPC products, thus decreasing the demand for uranium metal.

Today, the FMPC continues to investigate the effects that years of operation had on the environment. The Environmental Monitoring Program plays a key role in this effort. Like any complex program or investigation, the Environmental Monitoring Program was developed after careful consideration of many components. For example, FMPC production processes involved both radioactive and nonradioactive materials. Some of these materials and their waste products are hazardous and remain onsite. The program is largely based upon the flow of these materials and the locations of the

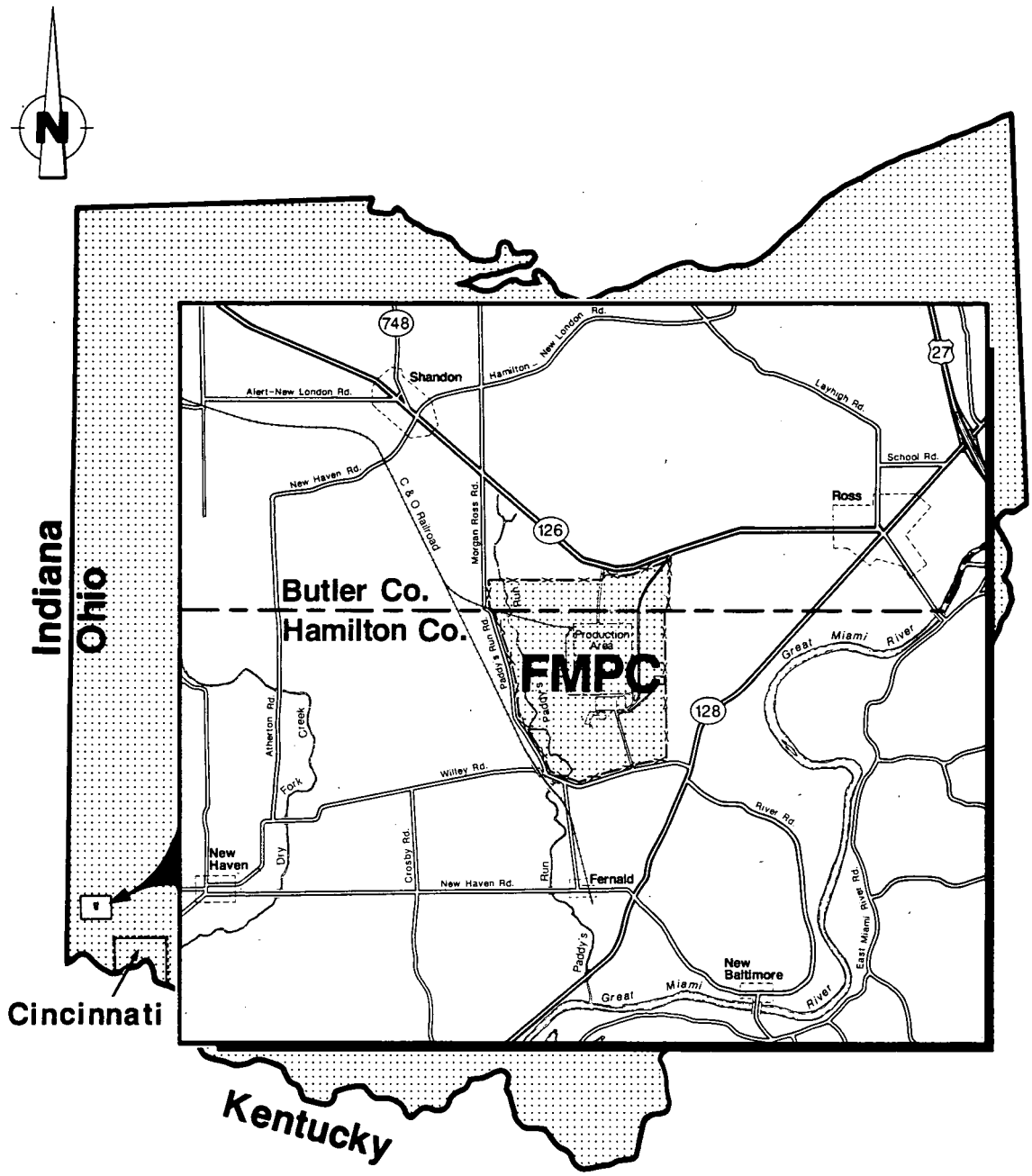



Figure 1. FMPC and Vicinity

storage sites. In addition, the program is regularly modified to reflect changing conditions.

# Status of Production Operations at the FMPC

The production level during the first half of 1989 was greatly reduced as compared to earlier years, and operations consisted mostly of processing waste residues. When production was suspended on July 10, most government production programs which used FMPC products were advised to find private-sector suppliers. The FMPC remains in standby for some segments of production until the government is confident commercial suppliers can meet future demand for uranium metal. Operations during the second half of 1989 were limited to containing and treating site effluents and packaging and shipping radioactive wastes for offsite disposal. The remainder of this chapter looks at many of the factors that influence the Environmental Monitoring program.

# Physical and Ecological Characteristics of the Area

The Great Miami River runs in a southerly direction about 1 km (0.6 mile) east and south of the FMPC. Upstream of the FMPC on the Great Miami River lie the communities of Fairfield, Hamilton, Middletown, and Dayton (Figure 2). Downstream areas are sparsely populated and have a few small industries. The Great Miami River flows into the Ohio River about 29 km (18 miles) south of the FMPC.

The FMPC is situated on a relatively level plain, about 177 meters (580 ft) above sea level. The land rises to 213 meters (698 ft) at the northern boundary and slopes downward to 168 meters (551 ft) at Paddy's Run, a small creek on the western boundary. Figure 3 presents a detailed overview of the FMPC site as it exists today.

## *Soil and Aquifer Descriptions*

At the FMPC, nearly 15 meters (49 ft) of clay-rich till, generally described as silty clay loam, overlie sand and gravel. Till is a

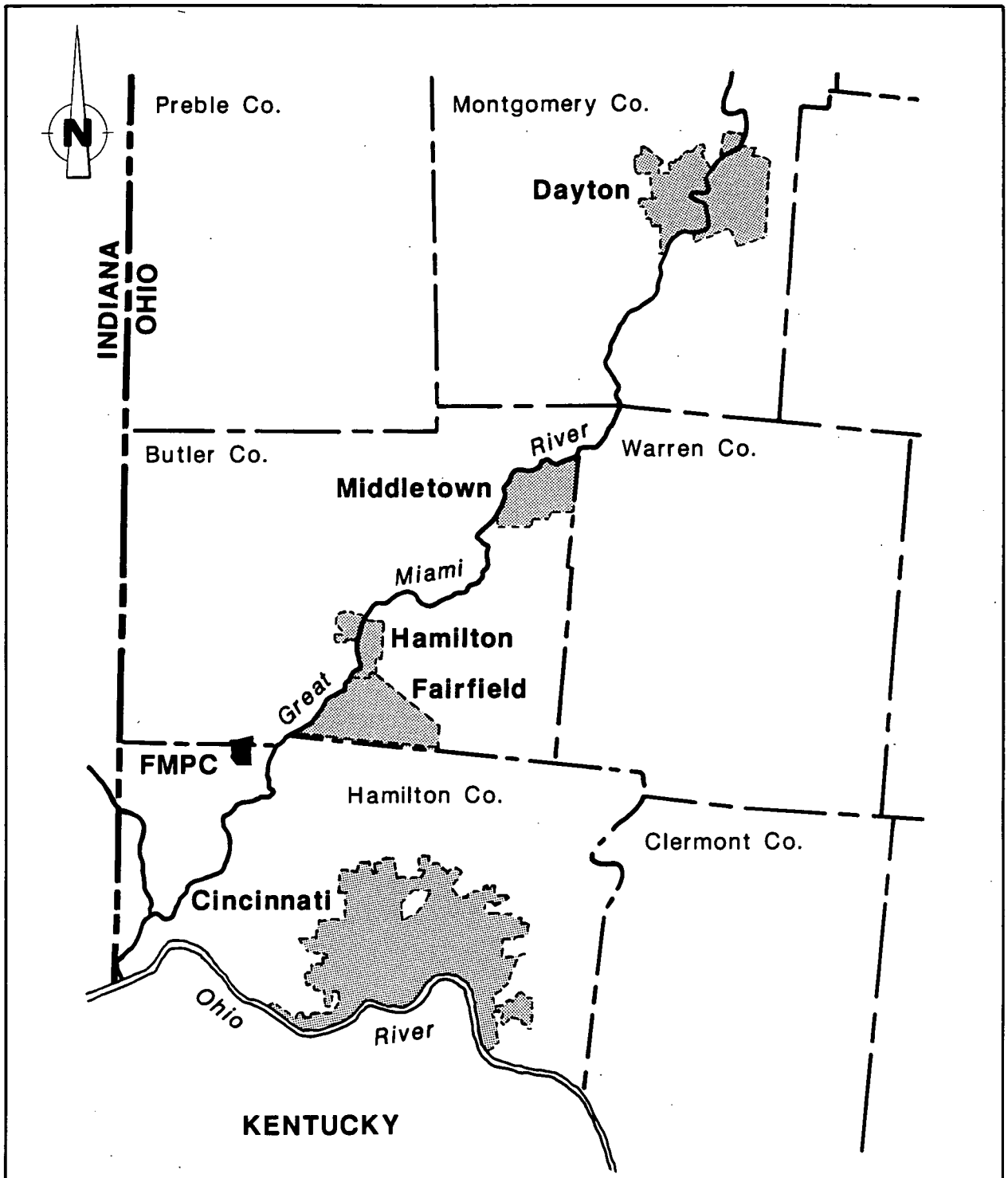



Figure 2. Major Communities In Southwestern Ohio

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mixture of unstratified clay, sand, and gravel that was deposited by glaciers during the ice age. North of the site, near Route 126, the till deposits directly overlie the bedrock. South of the site, Paddy's Run has eroded some of the till, exposing the sand and gravel aquifer underneath.

The sand and gravel deposits are about 5 km (3 miles) wide and 46 meters (151 ft) deep, and fill the remains of an ancient river valley that was cut into the bedrock. The Great Miami River presently flows through these deposits. Sand and gravel deposits often hold water, and, in fact, the area under the FMPC and vicinity is part of a large aquifer system in southwestern Ohio (Figure 4). This aquifer is a major source of fresh water for industries and residences. More than 60 meters (200 ft) below the surface of the FMPC lies bedrock consisting of alternating layers of limestone and shale (Figure 5).

Groundwater does not flow in the till as easily as it flows in the sand and gravel aquifer. Movement rates in the till near the waste pit area in the northwest corner of the site are about 4.3 to 6.7 meters (14 to 22 ft) per year. This can be compared to movement rates of 27 to 61 meters (90 to 200 ft) per year in the sand and gravel aquifer. In addition, flow directions are not as uniform in the till as in the sand and gravel aquifer because of the topography. Hills, gullies, woods, and other features, including the composition of the till itself, affect the water flow in the till.

As shown in Figure 4, the groundwater in the sand and gravel aquifer is moving east under the waste pit and production areas, while on the southern edge of the facility groundwater moves to the south. These groundwater flow data are used to track and forecast the movement of contaminants which may be found in the aquifer.

## Plant and Animal Populations

The plants found at the FMPC are typical for this region and consist of a variety of grasses and brush. Wooded and wetland areas also exist. The area north of the production area is moderately wooded with a variety of deciduous hardwoods. Pine trees were planted on several acres immediately north of the production area as part of an environmental improvement project in 1973. Naturally-wooded areas are also found along natural watersheds along Paddy's Run. Much of the remainder of the site is leased to local dairy producers

## (1A) BUILDING IDENTIFICATION

| Building I.D. No. | Grid Coordinates | Title |
|---|---|---|
| 00 | ** | General |
| 1a | C-3 | Preparation Plant |
| 1b | C-3 | Plant 1 Storage Building |
| 2a | B-3 | Ore Refinery Plant |
| 2b | B-3 | Lime Handling Building |
| 2c | B-3 | Bulk Lime Handling Building |
| 2d | B-3 | Metal Dissolver Building |
| 2e | C-3 | NFS Storage and Pump House |
| 3a | B-3 | Maintenance Building |
| 3b | B-3 | Ozone Building |
| 3c | B-3 | Control House |
| 3d | B-3 | NAR Towers |
| 3e | B-3 | Hot Raffinate Building |
| 3f | B-3 | Digestion Fume Recovery |
| 3g | B-3 | Refrigeration Building |
| 3h | B-3 | Refinery Sump |
| 4a | B-4 | Green Salt Plant |
| 4b | B-4 | Plant 4 Warehouse |
| 4c | B-4 | Plant 4 Maintenance Building |
| 5 | B-4 | Metals Production Plant |
| 6 | B-5 | Metals Fabrication Plant |
| 7 | B-4 | Plant 7 |
| 8a | B-3 | Recovery Plant |
| 8b | B-3 | Maintenance Building |
| 8c | B-3 | Rotary Kiln/Drum Reconditioning Building |
| 9 | C-5 | Special Products Plant |
| 10a | D-4 | Boiler Plant |
| 10b | D-4 | Boiler Plant Maintenance Building |
| 11 | A-4 | Service Building |
| 12a | C-4 | Maintenance Building (Main) |
| 12b | C-4 | Cylinder Storage Building |
| 12c | C-4 | Lumber Storage Building |
| 13a | A-3 | Pilot Plant Wet Side |
| 13b | A-3 | Pilot Plant Maintenance Building |
| 13c | A-3 | Sump Pump House |
| 14 | A-4 | Administration Building |
| 15 | A-3 | Laboratories |
| 16a | A-5 | Main Electrical Station |
| 16b | A-4 | Electrical Substation |
| 18a | C-2 | Surge Lagoon |
| 18b | B-3 | General Sump |
| 18c | C-4 | Coal Pile Runoff Basin |
| 18d | B-3 | Biodenitrification Towers |
| 18e | * | Storm Water Retention Basin |
| 18f | D-1 | Pit 5 Sluice Gate |
| 18g | C-1 | Clearwell Pump House |
| 18h | B-3 | BDN Effluent Treatment Facility |
| 19a | C-4 | Main Metal Tank Farm |
| 19b | A-3 | Pilot Plant Ammonia Tank Farm |
| 20a | C-4 | Valve/Control Building |
| 20b | D-4 | Filter/Chemical Building |
| 20c | C-4 | Cooling Towers |
| 20d | B-5 | Elevated Storage Tank (Potable $H_2O$) |
| 20e | B-3 | Well House #1 |
| 20f | B-3 | Well House #2 |
| 20g | A-3 | Well House #3 |
| 20h | D-4 | Process Water Storage Tank |
| 20j | B-2 | Lime Slurry Pits |
| 22a | B-5 | Gas Meter Building |
| 22b | A-3 | Stormsewer Lift Station |
| 22c | A-5 | Truck Scale |
| 23 | * | Meteorological Tower |
| 24a | D-3 | Railroad Scale House |
| 24b | C-4 | Railroad Engine Building |
| 25a | * | Chlorination Building |
| 25b | * | MH #175 |
| 25c | A-5 | Sewage Lift Station Building |
| 25d | * | U.V. Disinfection Building |
| 25e | * | Digester Control Building |
| 26a | B-3 | Pump House - H.P. Fire Protection |
| 26b | B-3 | Elevated Water Storage Tank |
| 28a | A-4 | Security Building |
| 28b | A-4 | Human Resources Building |
| 30a | C-3 | Chemical Warehouse |
| 30b | C-3 | Drum Storage Warehouse |
| 31 | A-5 | Engine House - Garage |
| 32 | D-5 | Magnesium Storage |
| 34a | B-1 | K-65 Storage Tank - North |
| 34b | B-1 | K-65 Storage Tank - South |
| 35a | C-1 | Metal Oxide Storage Tank - North |
| 35b | B-1 | Metal Oxide Storage Tank - South |
| 37 | A-3 | Pilot Plant Annex |
| 38 | D-4 | Propane Storage |
| 39a | B-3 | Incinerator Building |
| 39b | B-3 | Shelter Storage Building |
| 39c | B-3 | Incinerator Building Sprinkler Riser House |
| 44a | A-5 | Trailer Complex - 6-Plex - East |
| 44c | A-3 | Trailer Complex - 7-Plex - South |
| 44d | A-3 | Trailer Complex - 7-Plex - North |
| 44e | A-4 | Trailer Complex - 10-Plex |
| 45 | B-3 | Rust Engineering Building |
| 46 | A-5 | Heavy Equipment Garage |
| 51 | A-2 | $UF_6$ to $UF_4$ Reduction Facility II |
| 53a | A-4 | Occupational Safety & Health Building |
| 53b | A-4 | In-Vivo Building |
| 54a | A-3 | $UF_6$ to $UF_4$ Reduction Facility I |
| 54b | A-3 | Pilot Plant Warehouse |
| 55a | B-4 | Slag Recycling Plant |
| 55b | B-4 | Slag Recycling Pit/Elevator |
| 56 | D-3 | CP Storage Warehouse |
| 60 | D-3 | Quonset Hut #1 |
| 61 | D-3 | Quonset Hut #2 |
| 62 | D-3 | Quonset Hut #3 |
| 63 | D-4 | KC-2 Warehouse |
| 64 | D-5 | Thorium Warehouse |
| 65 | D-5 | (Old) Plant 5 Warehouse |
| 66 | C-3 | Drum Reconditioning Building |
| 67 | C-3 | Plant 1 Thorium Warehouse |
| 68 | A-3 | Pilot Plant Warehouse |
| 69 | D-5 | Decontamination Building |
| 71 | C-3 | General In-Process Storage Warehouse |
| 72 | C-3 | Drum Storage Building |
| 73 | * | Fire Brigade Training Center Building |
| 77 | C-5 | Finished Products Warehouse |
| 78 | * | New D&D Facility (On Hold) |
| 79 | B-5 | Plant 6 Warehouse |
| 80 | B-3 | Plant 8 Warehouse |
| 81 | C-5 | Plant 9 Warehouse |
| 82 | B-5 | Receiving & Incoming Materials Inspection Area |

* Outside of Perimeter Security Fence

**NOTE: Any Unidentified Area is Referred to as 00 General

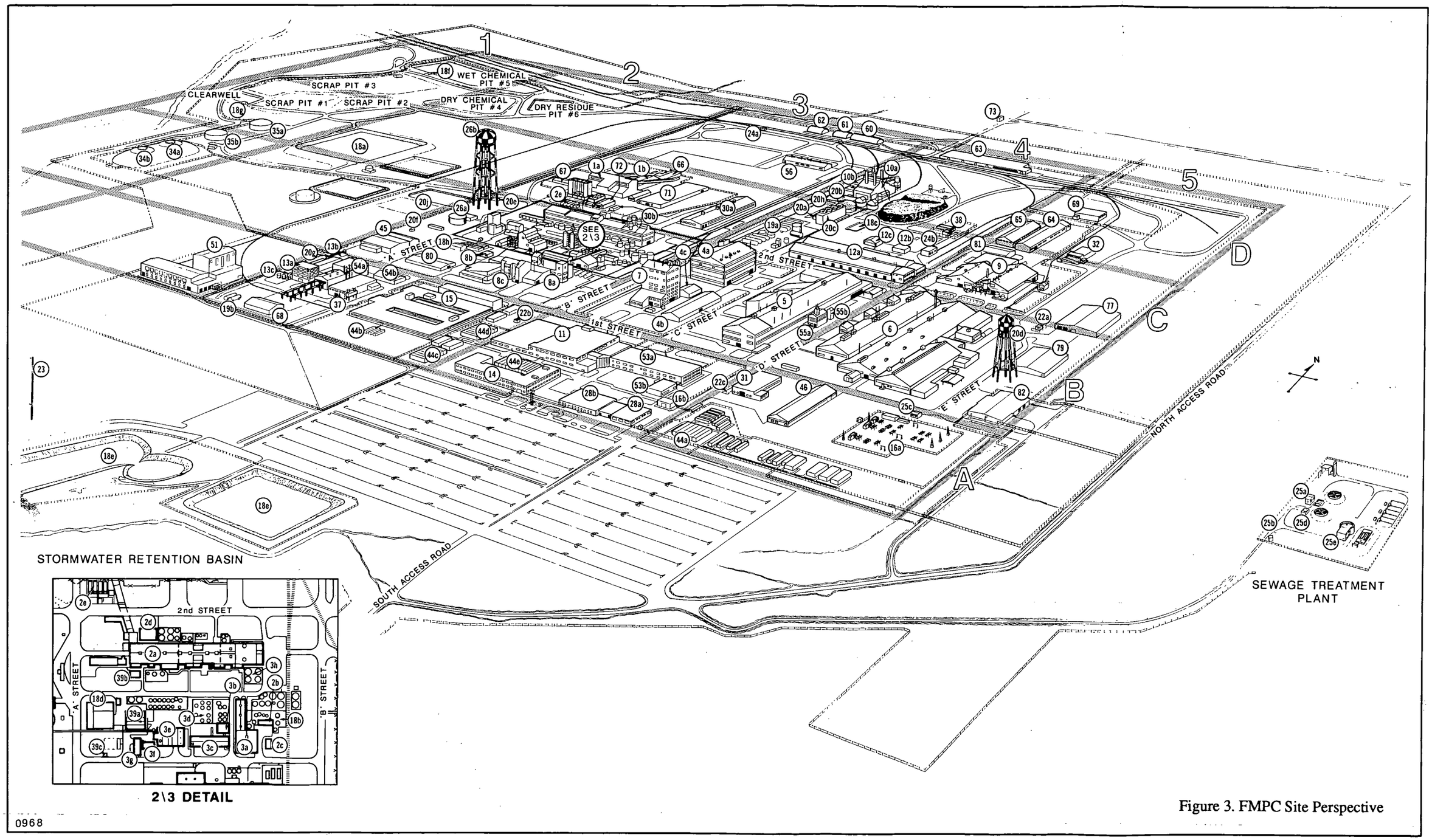


Figure 3. FMPC Site Perspective

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whose cattle graze on a variety of pasture grasses. Grasses and brush dominate the waste storage area.

This plant diversity provides abundant food and cover for wildlife, including eastern cottontails, woodchucks and pheasants. The pine plantation provides cover for deer and other animals and provides nesting areas for various species of birds, such as song sparrows, blue jays, cardinals, and robins.

White-tailed deer, bobwhite quail, scattered waterfowl, and other game species have been observed onsite. Paddy's Run provides habitat for several species of fish, including minnows, darters, and shiners. In 1989, there were no endangered species at the FMPC.[2]

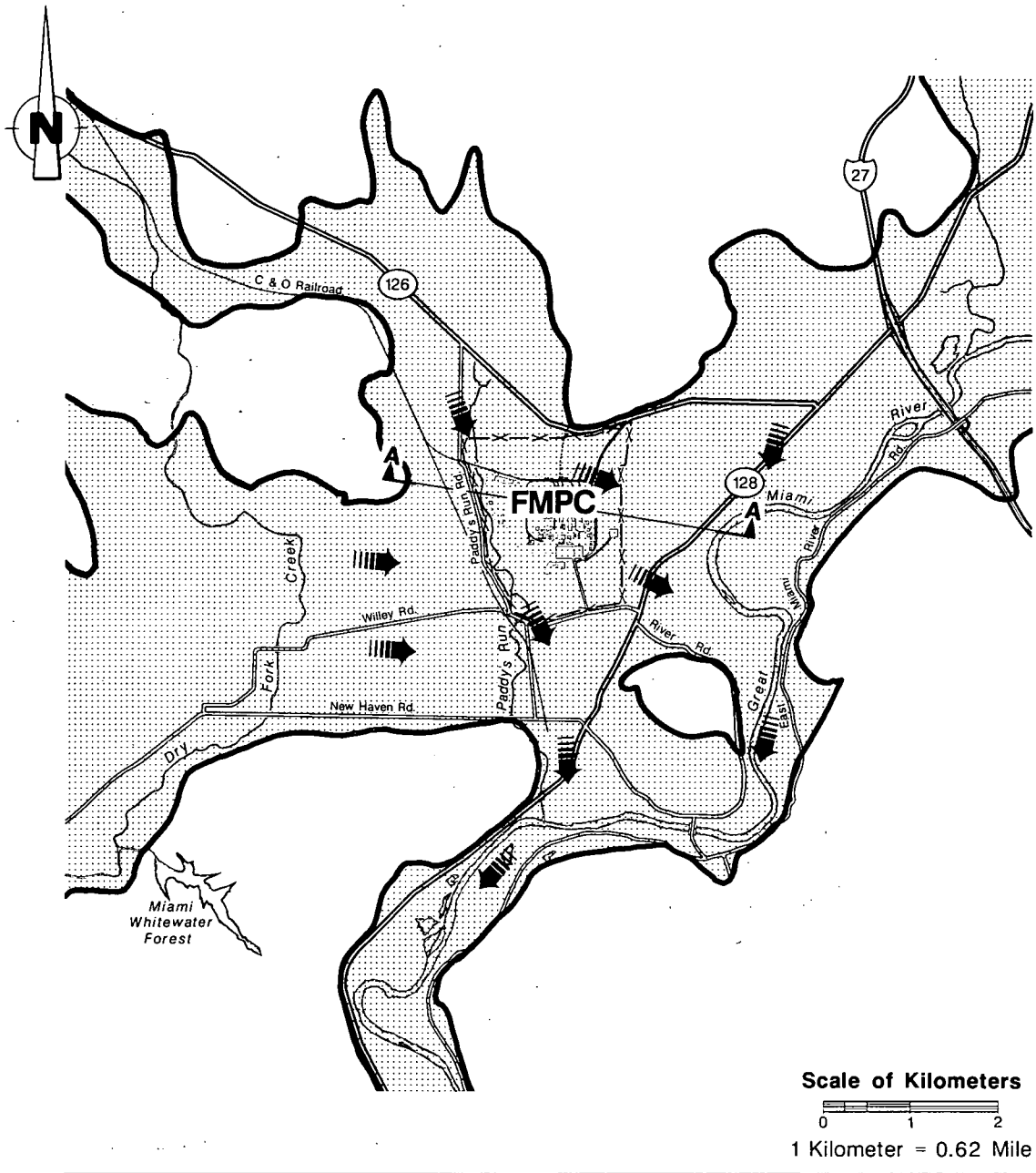
## Precipitation Data for 1989

The total rainfall for this area in 1989 was 126 cm (49.6 inches), considerably above the average rainfall of 103.02 cm (40.56 inches) for the years 1960 through 1989. The wettest month during 1989 was March when 16.3 cm (6.40 inches) fell. By contrast, the least precipitation was recorded in September when 7.54 cm (2.97 inches) fell. These figures were obtained from the Greater Cincinnati International Airport, located about 27 km (17 miles) south of the site. Precipitation data for the entire year were not available from the FMPC meteorological tower because of damage caused by lightning and subsequent maintenance and calibration procedures.

## Economic Activities in the Fernald Area

The major economic activities in the area around the FMPC are farming and raising dairy and beef cattle. These activities also account for the majority of the land use in the area. Major crops include field corn, sweet corn, soybeans, and winter wheat. Several nearby farms also sell produce locally or in nearby urban markets. The FMPC is also a source of income for the local area.

Other important commercial products from the area include sand, gravel, and water from the aquifer. Many gravel-pit operations exist along the Great Miami River and some distance inland. A water company is located 2 km (1.25 miles) upstream of the FMPC. Presently, this company pumps about 76,000 $m^3$ (20 million




## LEGEND

| | |
|---|---|
| Buried Channel Aquifer | Plant Perimeter |
| General Direction of Groundwater Flow | Location of Cross Section Shown in Figure 5 |

Figure 4. Buried Valley Aquifer Underlying the FMPC and Vicinity

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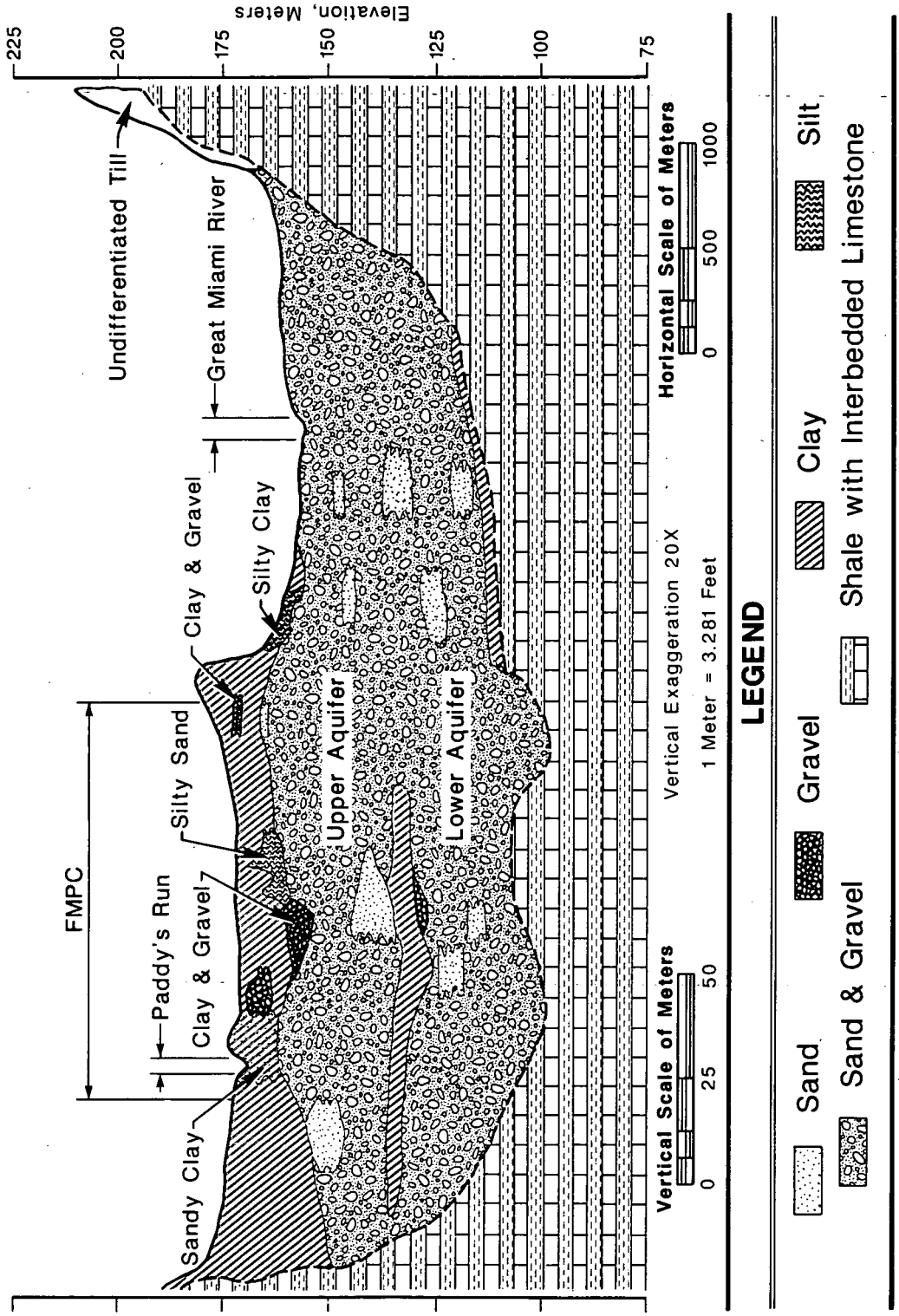



Figure 5. Cross Section of the Great Miami River Valley, Looking North

gallons) of groundwater per day, which it sells chiefly to industries in Greater Cincinnati.

# An Overview of Production Operations

Even though production has been suspended, an understanding of the production process is necessary in order to understand the basis for the ongoing Environmental Monitoring Program. The major steps in the production process are highlighted in Figure 6. A variety of materials were used in the process, including many that were received from other DOE sites. In fact, materials such as floor sweepings and dust collector and production residues were recycled in order to recover as much of the uranium as possible.

> Most of the uranium processed in recent years at the FMPC was depleted in the uranium-235 isotope, that is, it contained a smaller percentage of uranium-235 than does naturally-occurring uranium — less than 0.71%. (Isotopes are discussed in the next chapter, "Fundamentals of Radiation.")
>
> For many years, much of the uranium processed was slightly enriched (greater than 0.71% uranium-235) to no more than 1.25% uranium-235.

The first production steps involved chemical processing that ended with an intermediate product commonly called green salt (uranium tetrafluoride, $UF_4$). The green salt was then blended with magnesium-metal granules, placed in a closed reduction pot, and heated in furnaces in Plant 5. The product from this operation was uranium metal called a derby.

Some derbies were sent directly to other DOE sites, while the remainder were remelted, along with uranium scrap-metal recovered from earlier production, and poured into graphite molds to form ingots. Ingots varied in weight, size, and shape according to how they were used at the FMPC and at other DOE sites. Machining of these ingots occurred in Plants 6 and 9, after which the billets (machined ingots) were shipped to other DOE sites, principally Savannah River.

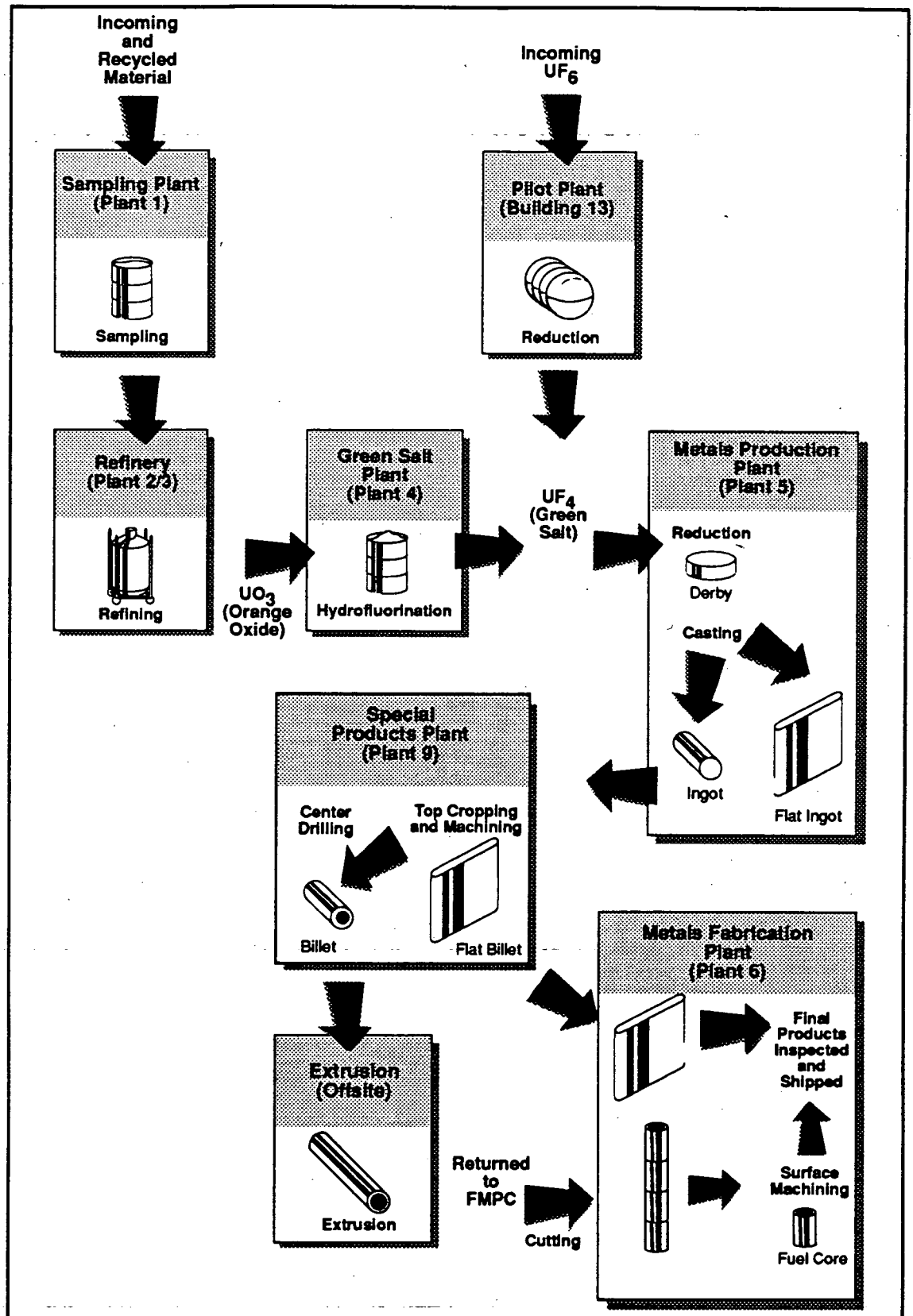



Figure 6. FMPC Production Process

# Handling and Storing Radioactive and Hazardous Materials

In addition to producing uranium metal, the FMPC has been storing materials used here and at other DOE sites. If these materials are released, they can affect the environment. Therefore the Environmental Monitoring Program samples the air and liquid pathways for materials stored onsite. Large quantities of radioactive and hazardous materials handled or stored onsite during 1989 included:

### Radioactive

- Pitchblende ore residues containing radium stored in the K-65 silos
- Thorium and thorium compounds stored in several locations within the production area
- Radioactive materials in the waste pits
- Uranium metal
- Uranium compounds
- Magnesium fluoride ($MgF_2$) contaminated with uranium
- Scrap metal contaminated with uranium

### Hazardous

- Nitric acid
- Ammonia
- Hydrochloric acid
- Sulfuric acid
- Methanol
- Process waste, including wastes regulated by the Resource Conservation and Recovery Act (RCRA).

The FMPC is adding buildings to store hazardous waste, repackaging some materials into new drums, and removing materials no longer needed for production. For example, two new warehouses originally built to store uranium products have been converted to meet the requirements for hazardous waste storage. Also, thorium previously stored in a deteriorating above-ground silo and several bins and the thorium stored in drums on an outdoor pad were packaged in new drums and are now stored in a warehouse. Plus, the FMPC began reducing its inventory of uranium hexafluoride, ground magnesium, and miscellaneous nonradioactive

chemicals from the laboratory in light of lower production requirements during 1989. In December 1988, the FMPC completed the sale of anhydrous hydrogen fluoride, thereby eliminating a principal hazardous material from the site. All large inventories of ammonia were removed from the site in April 1989.

# Exposure Pathways to Humans

An important aspect of the Environmental Monitoring Program is the examination of exposure pathways. Exposure pathways are the routes by which pollutants can escape from the FMPC and reach people. Within each pathway, a route may be quite complex and involve several types of radioactive and/or nonradioactive contaminants.

Factors that influence the pathway and its importance include wind speed and direction, water flow, type of pollutant released, population density and distribution, diet of residents, and the uses of the surrounding land. The most important pathways at the FMPC are air and water.

Although both radioactive and nonradioactive materials can reach people through the same pathways, this discussion will focus on radioactive contamination since this is of primary concern at the FMPC. Much of this report, and the nucleus of the Environmental Monitoring Program, focuses on radioactive contamination.

For the air pathway, Figure 7, some of the primary routes are breathing airborne contaminants (gases or particles of dust) and eating food products that could be contaminated from radionuclides that fall from the air (either directly or through the soil-roots-plant-cow-milk pathways).[3] Accordingly, the FMPC samples air emissions and collects soil, grass, produce, and milk samples to investigate the extent to which pollutants are transported from the FMPC via the air pathway. However, the largest contributor to overall estimated air emissions during 1988 and 1989 was the dust particles which were not emitted through a production stack but originated from the waste pit area. The concentrations of these particles, called fugitive dust particles, were estimated using a computer model.

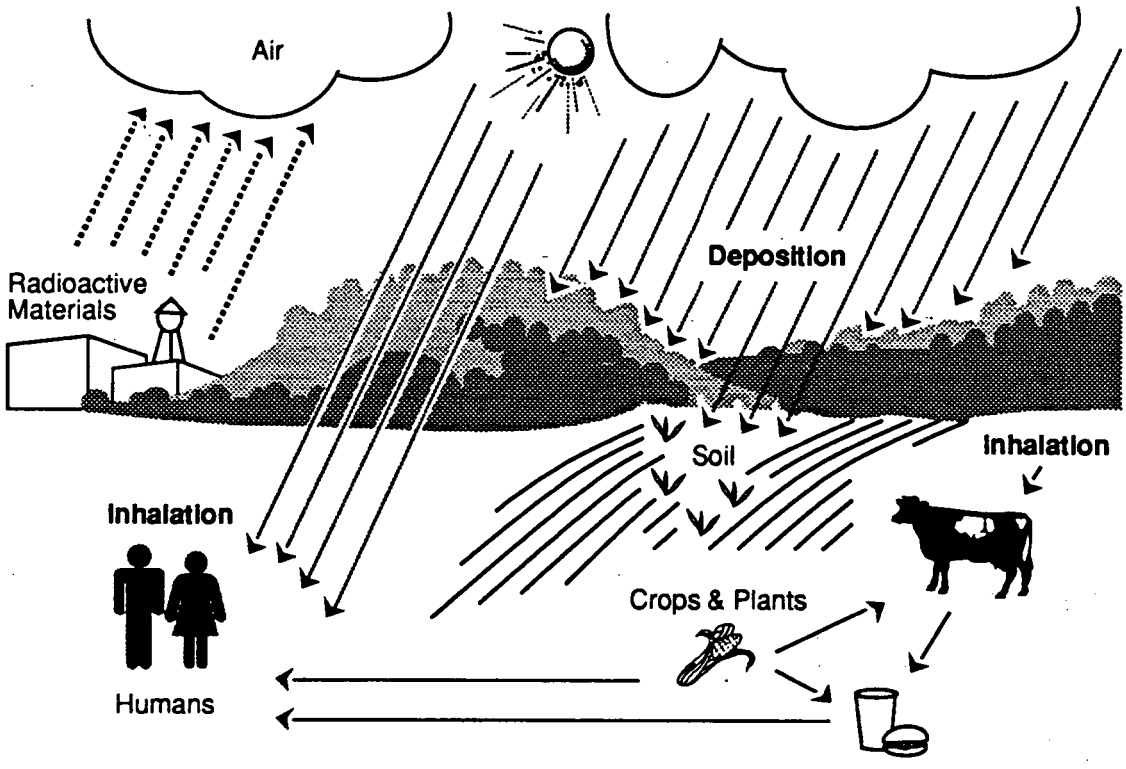



Figure 7. General Air Pathways to Humans

Figure 8 represents the many liquid pathways materials can take from their point of release through the environment to a human.[3] The liquid pathway is sampled and monitored at several locations onsite. The FMPC wants to ensure that its effluent meets all state standards, even though the river is not a source of public drinking water between the FMPC and the Ohio River. Though some people do fish in the Great Miami River, it is considered unsafe for swimming due to turbulence. The FMPC conducts routine surface water and sediment sampling in the Great Miami River and Paddy's Run, and annually samples fish from the river to determine if the plant affects the quality of the river and Paddy's Run.

A second component of the liquid pathway is the possible contamination of the groundwater, including through uncontrolled runoff from the production and waste storage areas. The FMPC has installed groundwater monitoring wells to collect data so the site can

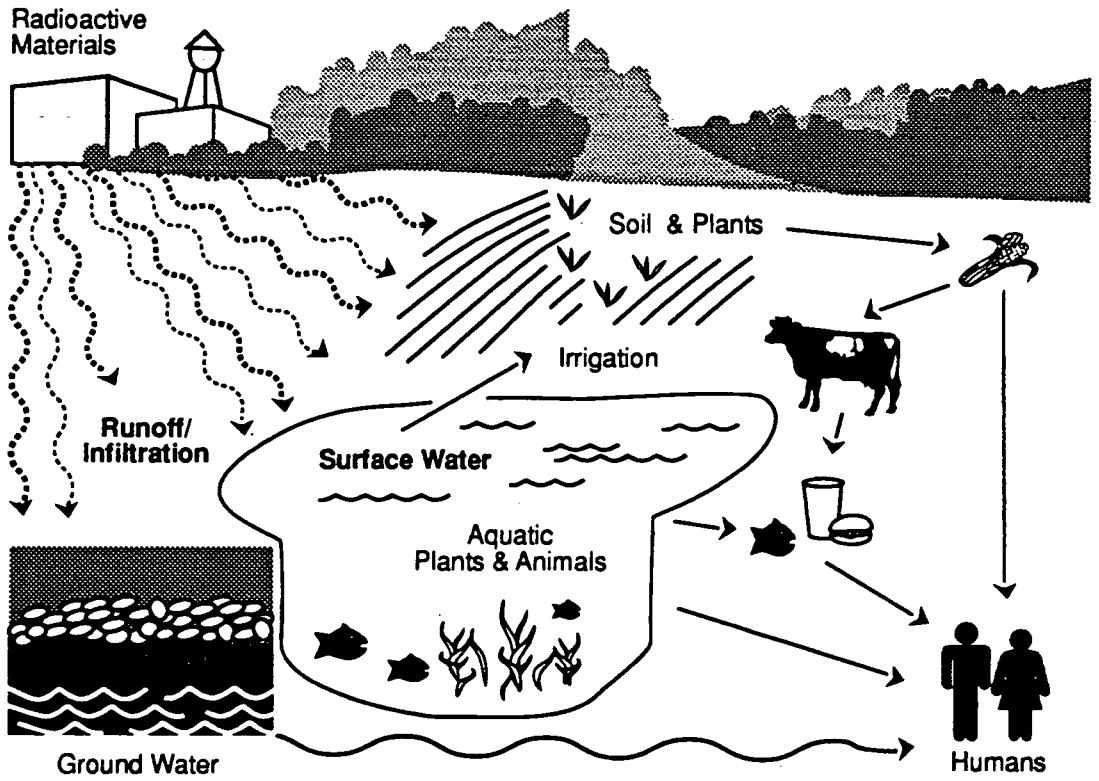



Figure 8. General Liquid Pathways to Humans

identify the extent of any contamination in the groundwater and develop plans to rectify the situation.

# Environmental Standards and Guidelines

Once the environmental monitoring data are analyzed, FMPC personnel compare the results to established standards and guidelines whenever possible. These standards and guidelines have been established by numerous national and international scientific and government groups, including National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), USEPA, OEPA, and DOE. Organizations such as these have studied the effects of radioactive and nonradioactive materials and how they move through the many pathways in the environment to humans, and from this have established standards and guidelines to ensure that employees,

people in the surrounding communities, and the environment are protected.

The DOE adopts standards recommended by the various groups of experts and publishes them in DOE Orders, thereby establishing the recommendations as limits to be met by the DOE facilities. For example, DOE Draft Order 5400.xx, "Radiation Protection of the Public and the Environment," defines the guidelines for radiation exposure to the public from discharges to the water and are based upon recommendations of International Commission on Radiological Protection (ICRP).[4, 5]

DOE Draft Order 5400.xx was replaced by DOE Order 5400.5 in February 1990. Since 5400.xx was in effect during 1989 and this report covers calendar year 1989, 5400.xx is referenced in this EMR. The EMR for 1990 will reference DOE Order 5400.5. There is no essential difference in the guidelines referenced in the two orders.

The guidelines state that the individual exposed to the greatest amount of radiation, the maximally-exposed individual, receives no more than 100 mrem (one mSv) per year effective dose. The maximally-exposed individual is that member of the community calculated to receive the highest effective dose based on the location of his or her home, weather conditions, and the critical pathway. Since the guideline for radon concentration in uncontrolled areas would result in an effective dose greater than 100 mrem per year, it is assumed to be excluded from the 100 mrem per year guideline in DOE Draft Order 5400.xx. The estimated doses from FMPC operations are presented and explained in Chapter Four.

The FMPC follows these standards and guidelines in its daily operations, and must report monitoring results on a regular basis to DOE, USEPA and OEPA. Examples of these reports include:

- Annual Radionuclide Air Emissions Report to DOE and USEPA
- NPDES Monthly Discharge Monitoring Report to OEPA
- Radiation Effluent Report to DOE, USEPA, OEPA, and Ohio Department of Health
- Radioactive Effluent Onsite Discharge/Unplanned Release Report to DOE
- Superfund Amendments and Reauthorization Act (SARA) 313 report to USEPA and OEPA.

Furthermore, this EMR publishes a summary of the data collected during the year for the Environmental Monitoring Program.

Throughout this report, specific standards for various pollutants are listed for comparison to the results of the FMPC Environmental Monitoring Program. There are some pollutants for which standards have not yet been established. Furthermore, there are instances where standards do not exist for parameters in specific media, such as uranium in soil, grass, produce, or fish. Where no standards or guidelines are available, other points of reference are presented in order to help the reader assess the impact of FMPC operations. For example, results are compared with control data from areas unaffected by the FMPC activities. 1989 results are also compared with results of previous years to look for possible trends.

# History of the FMPC Environmental Monitoring Report

Environmental Monitoring Reports for the FMPC have been issued regularly for the past 31 years. Format and content have changed greatly in that time.

The first FMPC Environmental Monitoring Report was published May 1, 1960 and covered calendar year 1959. The report contained two pages of text, two tables and two figures that summarized analytical results for air and water samples collected at the following locations:

- **Air** – sampling stations located at the four corners of the production area fenceline
- **Water** – where the FMPC effluent enters the Great Miami River and at upstream and downstream locations in the river (Ross and New Baltimore, Ohio).

Over the years, changes were made in the time periods covered by each report. For 1960 and 1961, quarterly reports were issued with an annual summary in the fourth quarter report. From 1962 to mid-1970, semiannual reports were issued with an annual summary in the second half report. A semiannual report was issued for first half

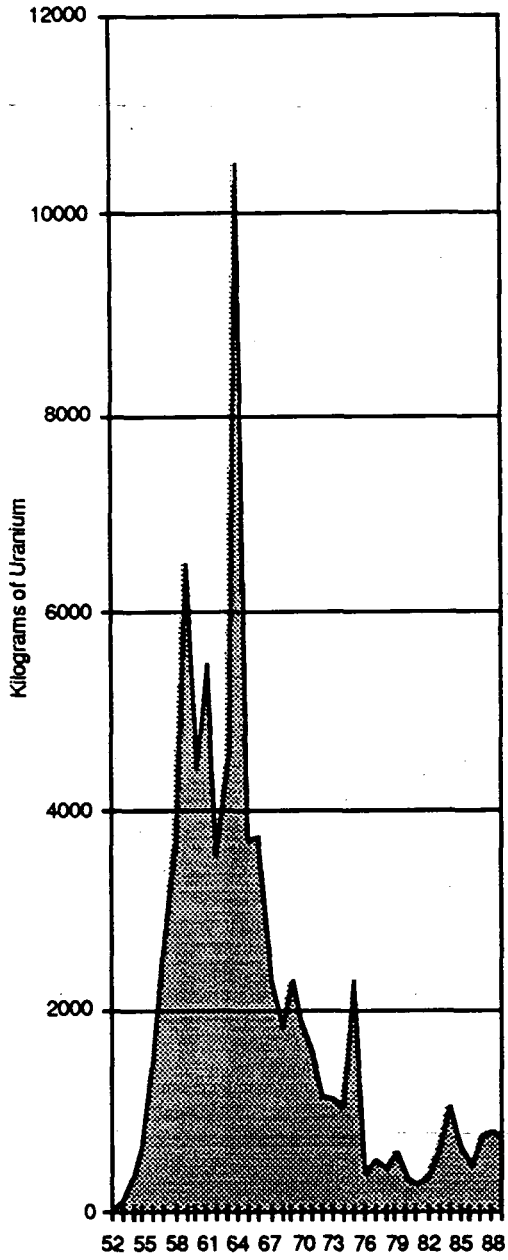
of 1971 and an annual report was issued for the entire year. Only annual reports were issued thereafter.

Report content also underwent a considerable change. The brief quarterly reports of the early 1960s evolved into more extensive documents which contained data for many radionuclides in samples collected at several hundred locations. Many additions to the report were a consequence of the requests that the public and governmental agencies should be provided with information that compared actual site discharges against regulatory standards and guidelines. The 1972 EMR, for example, was distributed to the USEPA, Ohio Department of Health, Ohio River Basin Commission, Commissioner of Health for the City of Cincinnati, Health Commissioner for Hamilton County, and the Atomic Energy Commission. Some data were reported to various government agencies before the first EMR was published. Liquid effluent results had been reported to the Ohio Department of Health on a monthly basis since at least 1954, and for many years duplicate samples from the Great Miami River were taken by FMPC personnel and a State engineer.

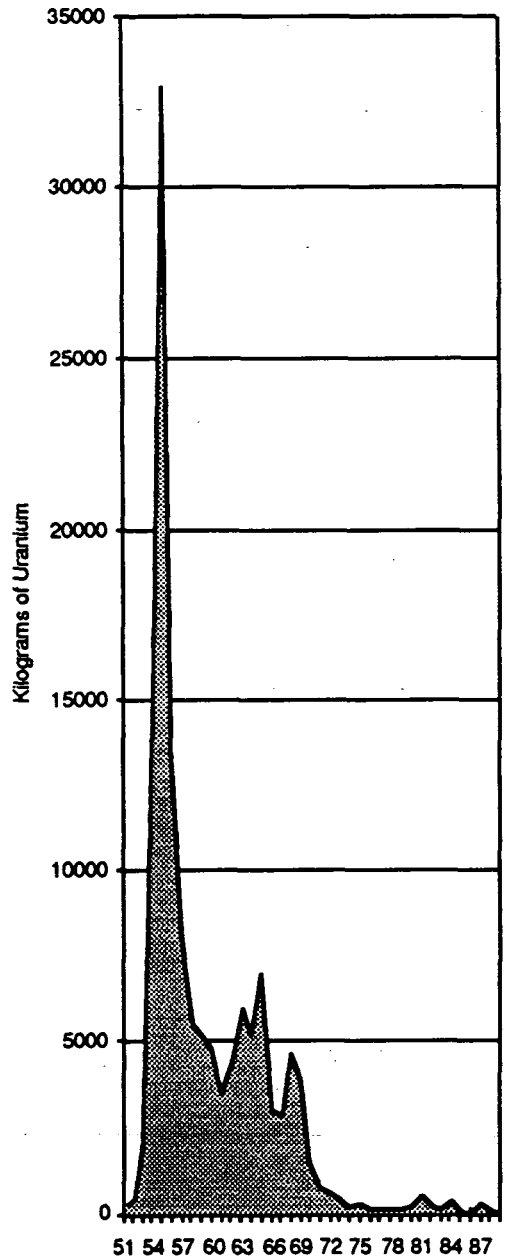
## TOPICS DISCUSSED IN THIS REPORT

Chapter Two, Fundamentals of Radiation, is a basic discussion of the atom, radiation, and effects of radiationon our health. Chapter Three, Results of the FMPC Environmental Monitoring Program for 1989, details the monitoring program. Estimated radiation doses are reported in Chapter Four, which describes how the data from the sampling program are used in computer models and in calculations to estimate effects of radiation exposures to individuals and population groups near the FMPC.

Chapter Five centers on quality assurance measures. The expanding waste management activities are described in Chapter Six, and Chapter Seven, Special Studies and Significant Events, covers a variety of environmental activities at the FMPC.




Yearly Record of Uranium
Discharged to the Great Miami River
(1952 - 1989)

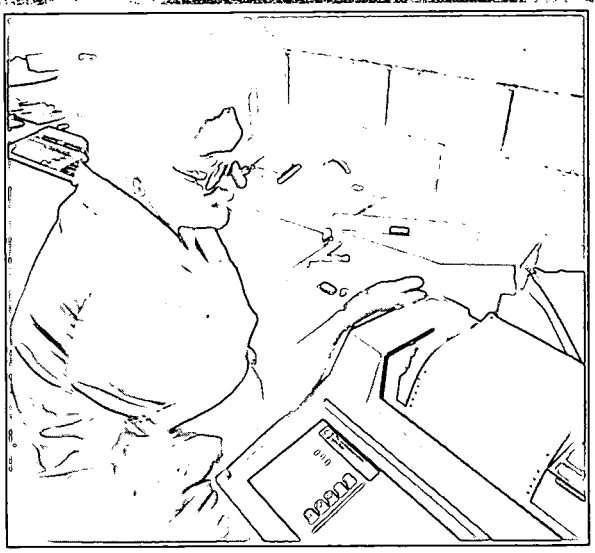


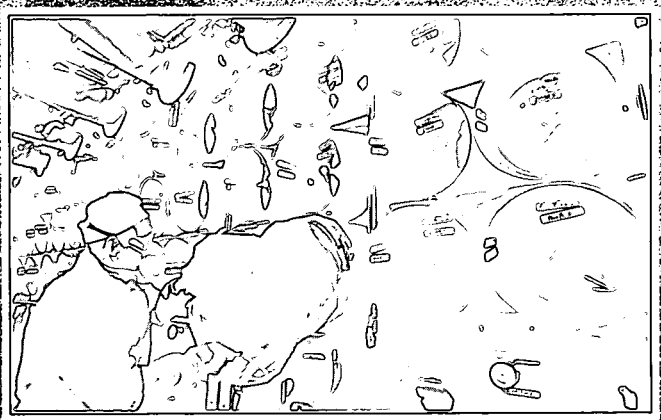

Yearly Record of Uranium
Discharged to the Air
(1951 - 1989)

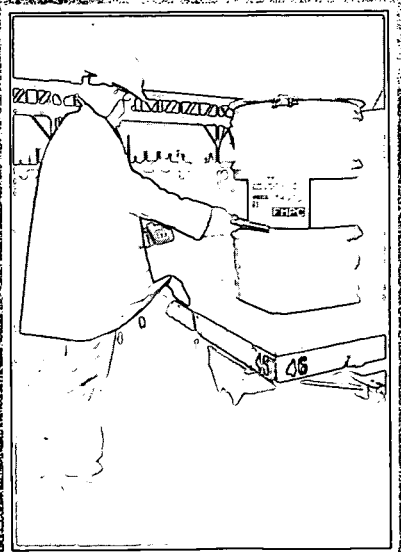
These graphs show the amount of uranium discharged to the Great Miami River and the air, respectively, throughout the years of FMPC operation. Total yearly data such as these eventually came to be commonplace in later Environmental Monitoring Reports.

# CHAPTER 2

# Fundamentals of Radiation







CHAPTER TWO

# Fundamentals of Radiation

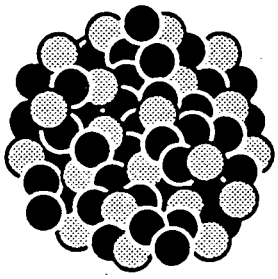
Since the FMPC works with radioactive materials, terms unique to radiation and its potential health effects are used extensively throughout this report. As a result, some of the important information in the report may be difficult for the nonscientist to interpret. This chapter provides a way to put that information into perspective, and includes the following topics:

- The atom
- The different forms of radiation
- The decay process
- The units used to measure radiation
- Background radiation
- The effects of low-level radiation
- Health risks.

If you are familiar with the concepts and terms used in the study of radiation, you may wish to proceed directly to the next chapter on the results of the FMPC Environmental Monitoring Program.

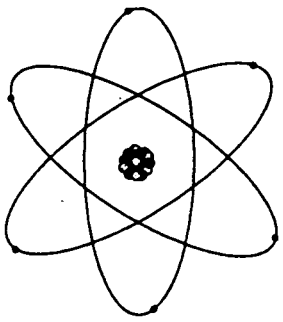
## The Atom

The world is made up of atoms. Atoms consist of two basic parts: the core, or nucleus, and the electrons orbiting the nucleus. The nucleus is made up of protons, which are positively charged, and neutrons, which have no charge. The electrons circling the nucleus have a negative charge. The electronic charge of an atom is very important. Since ordinary matter has a natural tendency to be stable, the atoms that make up matter must also be electrically neutral. To keep the atom electrically neutral, the number of electrons in an atom must equal the number of protons.



**The Nucleus of an Atom:**

This nucleus has many protons (light grey) and neutrons (black). Notice that there are never two protons touching each other. Similar to a magnet, the positively charged protons repel each other. There must be neutrons separating the protons.



**Electrons Orbiting the Nucleus:**

The electrons, like the protons, repel each other. Only two electrons can be on a path around the nucleus, and the two are always at opposite ends of the path. There will be as many paths as needed to hold all of the electrons.

Protons and electrons have many characteristics similar to magnets. Just as positive and negative magnetic poles are drawn toward each other, protons and electrons are pulled together. This attraction keeps the electrons orbiting around the nucleus. The reason that electrons are not pulled into the nucleus is because of the electrons' energy. This energy keeps them constantly moving and away from the protons. The energy in the electrons and the attraction of the electrons to the protons balance each other and keep the electrons in orbit. Just as there is energy in the electrons to keep them orbiting, there is energy in the nucleus to keep the protons and neutrons together.

The number of protons in the nucleus is referred to as the atomic number. The atomic number is the identifier of the atom. If it changes, the number of electrons and the chemical properties of the atom change. For example, for an atom to be hydrogen, it must have one proton. If a hydrogen atom were to gain a proton, it would no longer be hydrogen; it would be helium, which has two protons. Uranium must have 92 protons. Since protons are positively charged, the atom must also have 92 electrons, which are negatively charged, for it to be electrically neutral.

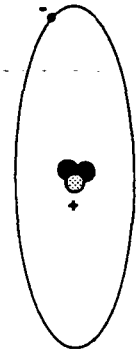
**The Hydrogen Nucleus:**

The hydrogen nucleus always has one proton and can have zero, one or two neutrons. The protons are positive and the neutrons are neutral.

Protons and neutrons are similar in size, and both of them are considerably larger than electrons (about 1,800 times more massive). Therefore the weight, and/or mass, of the atom is principally determined by the nucleus. The sum of the protons and neutrons in the atom is called the mass number.

Unlike protons, the number of neutrons a specific atom contains can vary since they have no charge and don't need to be balanced by electrons. Therefore the mass number can vary. For example, a

hydrogen atom always has one proton, but it can have either zero, one, or two neutrons. The different hydrogen atoms are called isotopes of hydrogen. Isotopes are labelled with their mass number. A hydrogen atom without a neutron is referred to as hydrogen-1 where 1 is the mass number. The hydrogen isotope with one neutron is referred to as hydrogen-2, and the isotope with two neutrons is referred to as hydrogen-3.



**The Hydrogen Atom:**

The hydrogen atom consists of the nucleus and the electron orbiting the nucleus. Since the hydrogen atom has one proton, it must have one electron to be electrically neutral.

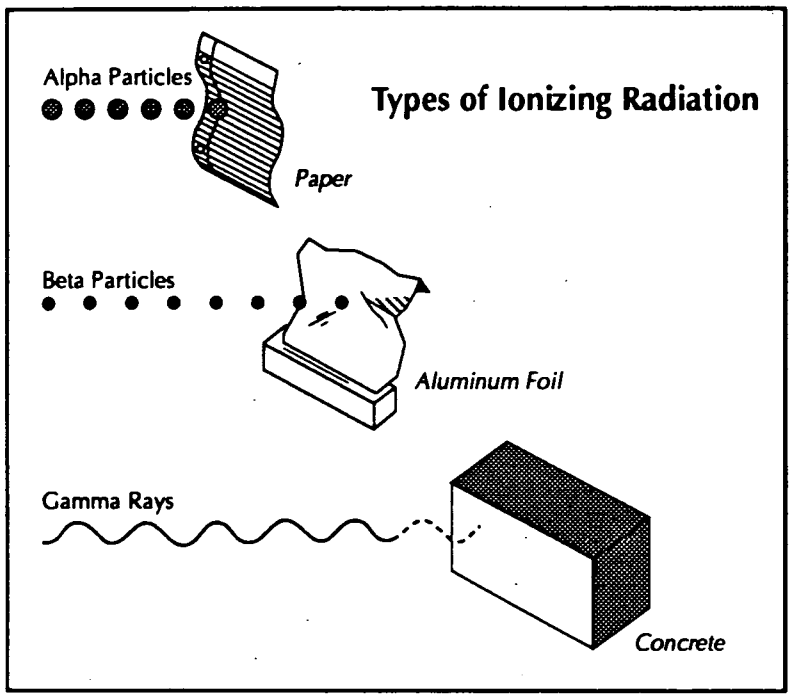
Most of the uranium at the FMPC contains 146 neutrons to go with the 92 protons present in every uranium nucleus; therefore, the mass number is 238 (146 neutrons + 92 protons = 238). Uranium-234 has 142 neutrons + 92 protons, uranium-235 has 143 neutrons + 92 protons, and uranium-236 has 144 neutrons + 92 protons. All of the isotopes of uranium are radioactive, and all decay by emitting an alpha particle as described in the next section.

# Radiation and Radioactivity

Radioactivity is a process in which a nucleus of an atom becomes unstable and spontaneously decays, or disintegrates. Radiation refers to the energy that is released in the form of particles or waves when the disintegration or decay of the nucleus occurs. This section includes a discussion on the three main forms of radiation produced by radioactivity: alpha particles, beta particles, and gamma rays.

## *Alpha Particles*

Alpha particles consist of two protons and two neutrons and have a positive charge. Because they are charged, they interact with other atoms by scattering off other charged particles or are absorbed by a molecule, thus losing their energy. Moreover, because of their large size, alpha particles do not travel very far when released (one to eight centimeters in air). They are unable to penetrate any solid material, such as paper or skin, to any significant depth. However,




if alpha particles are released inside the body, they can damage the soft internal tissues because they deposit all their energy in a very small volume. Radioactive uranium releases alpha particles, so if uranium particles are inhaled or swallowed, biological effects may occur. Other radionuclides present at the FMPC that decay by emitting alpha particles include thorium-228, -230, and -232.

## Beta Particles

Beta particles are electrons and carry a negative electrical charge. They are much smaller than alpha particles and travel at nearly the speed of light, thus they can travel for longer distances in air and penetrate solid materials more readily than alpha particles. Beta particles have the same effect as alpha particles, but since they are smaller, faster, and have less charge, they cause less concentrated damage when interacting with tissue. Radioactive thorium-234, a decay product of uranium-238, releases beta particles.

## Gamma Rays

Gamma rays are bundles of electromagnetic energy which behave as though they were particles. These pseudo particles can be thought of as a bundle of energy called photons. They are similar to visible light, but of a much higher energy. For example, X-rays are a type of high-energy electromagnetic radiation, and excessive exposure to X-rays can damage the body. Gamma rays are even more energetic than X-rays. They can travel long distances and can penetrate not only skin, but depending on their energy, can penetrate substantial distances into solid materials such as concrete or steel. Gamma rays are often released during radioactive decay along with alpha and beta particles. Some of the materials stored in the K-65 Silos at the

FMPC decay by emitting gamma rays. Potassium-40 is an example of a naturally-occurring radionuclide found in all human tissue that decays by emitting a relatively high-energy gamma ray.

## Radioactive Decay

As mentioned in the beginning of this section, radioactivity is a process in which a nucleus of an unstable atom spontaneously decays and releases energy. When most radioactive elements found in nature decay, the resulting atom is also radioactive. This is called a radioactive decay chain. There are several natural radioactive decay chains. A common chain begins with uranium-238 and ends with lead-206 (this isotope of lead is stable, which means it does not decay). Each of the various radioactive atoms (radionuclides) created during the decay sequence has its own natural rate of decay.

The uranium decay sequence is an example common in nature and here at the FMPC. (The uranium and thorium decay chains are presented on the next page.) Uranium-238 emits an alpha particle (two protons and two neutrons) and becomes thorium-234. Then a neutron in thorium-234 becomes a proton and an electron. The electron is emitted as a beta particle. Then thorium-234 decays to protactinium-234. The decay process proceeds in this manner.

It takes a different amount of time for each element to decay to the next element in the chain. The amount of time it takes for a radioactive substance to lose half of its radioactivity, or for half of it to become the next element in the chain, is its half-life. All decay chains found in nature begin with an isotope with an extremely long half-life. It is assumed that these atoms were formed at the same time as all the other atoms on earth and are still present because their half-lives are comparable to the age of the earth.

## Interaction with Matter

When radiation interacts with other materials, it affects the atoms of those materials principally by knocking the negatively charged electrons out of orbit. This causes the atom to lose its electrical neutrality and become positively charged. An atom that is charged, either positively or negatively, is called an ion. Anything that creates an ion is said to be ionizing.

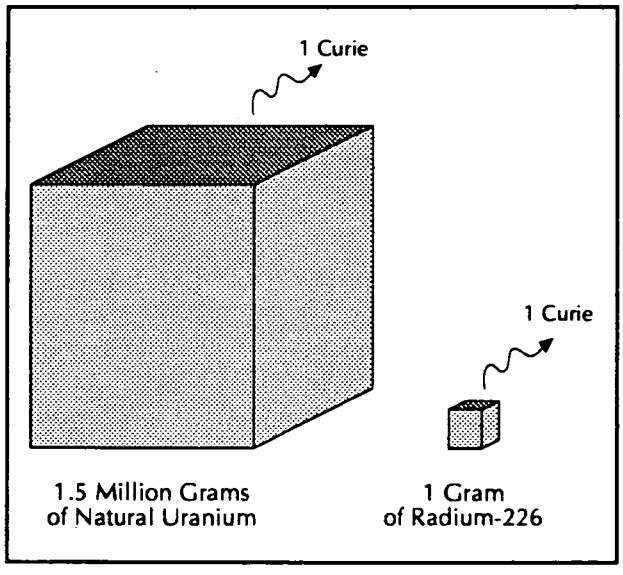
| Nuclides Of The Uranium Decay Chain | | |
|---|---|---|
| **Isotope** | **Half-life** | **Radiation** |
| Uranium-238 | $4.5 \times 10^9$ years | alpha |
| Thorium-234 | 24 days | beta, gamma |
| Protactinium-234m | 1.2 minutes | beta, gamma |
| Uranium-234 | $2.5 \times 10^5$ years | alpha, gamma |
| Thorium-230 | $8.0 \times 10^4$ years | alpha, gamma |
| Radium-226 | 1622 years | alpha, gamma |
| Radon-222 | 3.8 days | alpha |
| Polonium-218 | 3.05 minutes | alpha |
| Lead-214 | 26.8 minutes | beta, gamma |
| Astatine-218 | 2.0 sec | alpha |
| Bismuth-214 | 19.7 minutes | beta, gamma |
| Polonium-214 | $1.64 \times 10^{-4}$ seconds | alpha, gamma |
| Thallium-210 | 1.3 minutes | beta, gamma |
| Lead-210 | 22 years | beta, gamma |
| Bismuth-210 | 5.0 days | beta |
| Polonium-210 | 138 days | alpha, gamma |
| Thallium-206 | 4.2 minutes | beta |
| Lead-206 | Stable | |

| Nuclides Of The Thorium Decay Chain | | |
|---|---|---|
| **Isotope** | **Half-life** | **Radiation** |
| Thorium-232 | $1.4 \times 10^{10}$ years | alpha |
| Radium-228 | 6.7 years | beta |
| Actinium-228 | 6.13 hours | beta, gamma |
| Thorium-228 | 1.9 years | alpha, gamma |
| Radium-224 | 3.64 days | alpha, gamma |
| Radon-220 | 55 seconds | alpha |
| Polonium-216 | 0.16 seconds | alpha |
| Lead-212 | 10.6 hours | beta, gamma |
| Bismuth-212 | 60.5 minutes | alpha, beta, gamma |
| Polonium-212 | $3.04 \times 10^{-7}$ seconds | alpha |
| Thallium-208 | 3.1 minutes | beta, gamma |
| Lead-208 | Stable | |

**Example** – To illustrate the idea of decay sequence and decay chain, let's look at the isotope thorium-234. Its half-life is 24 days. If you started with 1,000 atoms of thorium-234, after 24 days you would have 500. After another 24 days you would have 250, and so on. The half-life of some isotopes, such as uranium-238, is very long. The middle column in the uranium and thorium decay chain examples contains the half-life periods of the elements in the decay chain. All of the radionuclides in the Uranium Chain can be thought of as "potential" lead-206 atoms. This will be the case many billions of years into the future when all natural radioactive isotopes will have decayed to their stable end products.

# Units of Measurement

To measure the effect of radiation, scientists have developed ways to measure levels and intensity of radiation. Some of these measurement units are technical and may require some explanation. Additional terms are included in the glossary to this report.




## *Activity*

Activity is the number of nuclei in a material that decay per unit of time. An amount of radioactive material which decays at a rate of 37 billion atoms per second has an activity of one curie (Ci). Smaller units of the curie are often used in this report. Two common units are the microcurie (μCi), one millionth of a curie, and the picocurie (pCi), one trillionth of a curie. The amount of radioactive material to emit one curie depends on the disintegration rate. For example, one gram of radium-226 is one curie of activity, but it would require about 1.5 million grams of natural uranium to equal one curie since radium-226 is more radioactive than natural uranium.

## Dose equivalent

When a person comes into contact with radiation, that person has been exposed to radiation. Exposure is the amount of radiation that is delivered to the body. Alpha, beta, and gamma radiation affect the body to different degrees. To take these different effects into account, each type of radiation is assigned a quality factor (QF). The more damaging the type of radiation, the higher the QF. For beta and gamma radiation, the quality factor is one. For alpha radiation, the quality factor is twenty. A different unit of measurement called the dose equivalent, or simply dose, is used when comparing the effects of different types of radiation. The dose equivalent is expressed in a unit called rem. The more rem, the higher the potential damage. Since the amount of radiation we receive from natural background and the FMPC is so small, millirem (mrem) is often used instead of rem. One mrem is equal to 1/1000 of a rem.

> In this report, we use the term ***dose*** frequently. Unless specified differently, that term will be used in place of the term ***dose equivalent.***

The term dose is used in four different ways in this report: organ dose, effective dose, committed effective dose, and whole body dose.

**The organ dose** is the amount of radiation received by an individual organ in the body. The amount of radiation any organ will absorb depends upon a variety of factors (for example, the way the radiation entered the body and the type of radiation). Therefore when discussing the organ dose, scientists often refer only to the organ of greatest importance called the critical organ. The critical organ varies from situation to situation. It is chosen based on things such as the amount of radiation received, the chemistry of the radionuclide, the sensitivity of that organ to the particular form of radiation, and the importance of that organ to the body. Based on the radionuclides found at the FMPC, the critical organs have been identified as the lung, kidney, and bone surface (endosteum). The National Emission Standards for Hazardous Air Pollutants (NESHAP) requires that the exposure to the maximally-exposed organ be limited to no more than 75 mrem per year from radionuclides released via the air pathway.[6]

**The effective dose** expresses how much of a health risk doses of radiation pose to individuals. To determine the effective dose,

scientists first estimate each organ dose. Then, since some organs are more sensitive to radiation than others, the organs are given differing weighting factors, similar to quality factors. The greater the risk an organ has of developing cancer and the more important that organ is to human health, the higher the weighting factor. The weighting factor is multiplied by the organ dose for each organ. These numbers are then added together to give the effective dose.

The NCRP recommends that an individual be exposed to no more than 100 mrem effective dose per year (over and above the amount

| Organ or Tissue | Weighting Factor |
|---|---|
| Gonads | 0.25 |
| Breasts | 0.15 |
| Red Bone Marrow | 0.12 |
| Lungs | 0.12 |
| Thyroid | 0.03 |
| Bone Surfaces | 0.03 |
| Remainder | 0.30 |

"Remainder" means the five other organs with the highest dose (e.g., liver, kidney, spleen, thymus, adrenal, pancreas, stomach, small intestine, or upper and lower large intestine, but excluding skin, lens of the eye, and extremities). The weighting factor for each of these organs is 0.06.

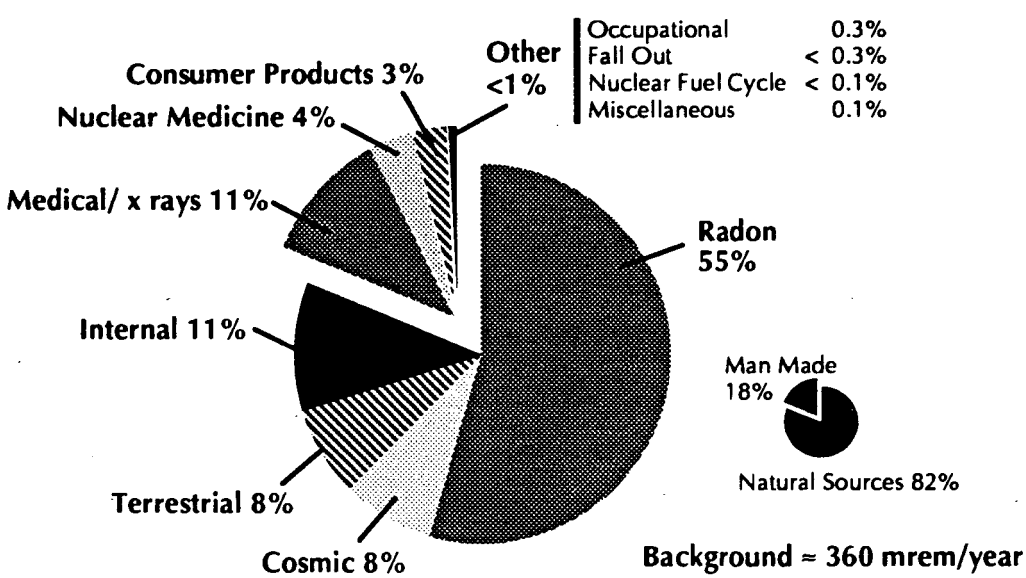
a person receives from background and medical radiation). This recommendation applies to the general public for long-term, continuous exposures.[7]

**The committed effective dose** is the total amount of radiation an individual receives over a specified period of time from radioactive materials inside the body. When a person breathes or eats something that contains radioactive materials, the radiation within those materials is not all released at once. Half of the radiation is released over a period of time equal to the half life of the radioactive material. Meanwhile, the body excretes radioactive materials at various rates determined by an individual's metabolism and the biochemistry of the radioactive material. Scientists have developed the concept of the committed effective dose to estimate the total amount of radiation you will receive over time (generally a 50-year period) from the radioactive materials you took into your body in a given time period. The DOE guideline for committed effective dose to a member of the public is 100 mrem per year.

**The whole body dose** is the amount of radiation an individual receives when the entire body is irradiated evenly. The whole body refers to almost all tissue and organs. Most radionuclides present at the FMPC do not contribute toward a whole body dose because they tend to concentrate more in some organs than others.

# Exposure to Background Radiation

The dose terms defined in the preceding paragraphs apply to more than the radiation we may be exposed to from facilities like the FMPC. We are constantly exposed to what is called background radiation. This includes the decay of radioactive elements in the earth's crust, a steady stream of high-energy particles from space called cosmic radiation, naturally-occurring radioactive isotopes in the human body like potassium-40, medical procedures, man-made phosphate fertilizers (phosphates and uranium are often found together in nature), and even household items like televisions.[8] In the United States, a person's average annual exposure from




National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States*, NCRP-93, 1987.

background radiation is 360 mrem.[7] The DOE's guidelines (as well as other radiological guidelines) apply to exposures we receive in addition to background radiation.

| Personal Radiation Dose Counter* | |
|---|---|
| **Source of Radiation** | **Annual Dose** (mrem) |
| **Earth and Sky** | |
| Cosmic radiation at sea level | 26 |
| Cosmic radiation above sea level | |
| Add 1 mrem for every 100 feet above sea level (Cincinnati is approximately 600 feet above sea level.) | 6 |
| Radon | 200 |
| Nuclear testing fallout | 5 |
| **FMPC — Air Pathway** | |
| If you live very close to the plant, enter the maximum (5.2 mrem**). Otherwise, use the average 0.024 mrem. This is actually the amount you would receive over 50 years. But to be conservative, assume you received it all this year. | |
| **FMPC — Radon** | |
| Multiply the fraction of time in 1989 spent very close to the FMPC by 72 mrem (e.g., 1 month = 6 mrem). Enter this value: | |
| **Yourself** | |
| Your body | 40 |
| Jet plane travel | |
| Add 1 mrem for every 2500 miles flown | |
| Television viewing | |
| Add 0.15 mrem for each hour of viewing per day (For example, if your watch an average of 4 hours of TV a day in 1989, add 0.6 mrem.) | |
| **Medical** | |
| X-Ray and Radiopharmaceutical Diagnosis | |
| Add 10 mrem for each chest x-ray | |
| Add 500 mrem for each lower gastrointestinal-tract x-ray procedure | |
| Add 300 mrem for each radiopharmaceutical examination | |
| **Total** | |

* The information is drawn from two major sources: BEIR Report-III-National Academy of Sciences, Committee on Biological Effects of Ionizing Radiation, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences, Washington, DC, 1980 and National Council on Radiation Protection and Measurements Report No. 93, 1987.

** The method for estimating this dose is explained in Chapter Four.

As the Background Radiation Chart shows, radon is the largest contributor to background radiation. At an average of 200 mrem per year, naturally-occurring radon accounts for more than half of the background dose in the United States.[5]

One way to measure how much radiation we are exposed to is to complete a personal radiation dose counter.

The next section provides information on the effects of low-level radiation, whether it is naturally occurring or originates from a facility like the FMPC.

# Effects of Low-Level Radiation

The effects of radiation on humans are divided into two categories, somatic and genetic. Somatic effects are those that develop in the directly exposed individual, including a developing fetus. Genetic effects are those that are observed in the offspring of the exposed person.

Because we are constantly exposed to both natural and man-made sources of radiation, and because the body has the capacity to repair damage from low levels of radiation, it is extremely difficult to determine the effects from low-level radiation. This section explains why this is true and how somatic and genetic effects may occur.

## *Somatic Effects*

A dose of 1,000 rem of radiation delivered instantaneously will probably kill a human. A dose of 600 to 1,000 rem causes severe sickness, but there is some chance for recovery. A dose of 200 to 600 rem causes some sickness with a very good chance for recovery. A dose of 100 to 200 rem could possibly cause some vomiting, but probably no demonstrable long-lasting effects.[9]

Significant clinical symptoms of radiation probably won't be seen in individuals who have been exposed to less than 100 rem.[10] Most scientists believe that there are no directly observable short-term radiation effects on human beings exposed to less than 10 rem because the biological damage created by this level of radiation is too small to result in near-term clinical symptoms.

Continuous exposure to lower levels of radiation can produce gradual somatic changes over extended time. For example, someone may develop cancer from man-made radiation, background radiation, or some other source not related to radiation. Because all illnesses caused by low-level radiation can also be caused by other factors, it is presently impossible to determine individual health effects of low-level radiation. However, there are a few groups of people under medical observation because they have been exposed to higher levels of radiation. These include the survivors of Hiroshima and Nagasaki, uranium miners in the United States and eastern Europe, a group of workers who used paint containing radium, early users of X-ray machines, some Department of Energy employees working in the defense facilities, and people suffering from illnesses where radioactive material was used for treatment.

Even after studying the health effects of radiation on these groups, scientists are still not able to determine with certainty how much cancer may have been caused by low-level radiation.

Those exposed to high levels of radiation are at greater immediate risk. We know this because at these higher radiation doses, we see that the number of radiation effects increases as the level of radiation dose increases.

This relationship is not so obvious when dealing with low-level radiation. Scientists have not been able to demonstrate that there is an increase in the number of radiation effects when there is an increase in low-level radiation.[8] In other words, we do not know if there is a certain radiation level, or threshold, below which humans can be exposed without causing medical problems to the exposed individual.

Estimates on the value of the threshold level for radiation, if it exists, vary significantly. As mentioned earlier, some scientists believe it could be as high as 10 rem.[9] Others insist there is no threshold level below which radiation exposure is safe.[11] They feel there is always a direct relation between the amount of radiation to which people are exposed and the number of related radiation effects.

Certain somatic effects have been documented only at high radiation levels. These include clouding of the lens of the eye, lowered fertility rate, and a reduction of the number of white cells in the

blood. Problems caused by radiation seen in the development of the embryo apparently result from large doses, not the low levels characteristic of natural background radiation. Therefore, the most likely somatic effect of low-level radiation is believed to be some increased risk of cancer.[8]

## Genetic Effects

A single ionizing event has the potential to cause a genetic effect. To understand why this is true, it is helpful to look at the structure of a human cell.

Human cells normally contain 46 chromosomes; 23 transmitted from the mother, and 23 from the father. These 46 chromosomes contain about 10,000 genes which are passed on to the next generation and which determine many physical and psychological characteristics of the individual.

Radiation can cause physical changes or mutations in these genes. Chromosome fibers can break and rearrange causing interference with the normal cell division of chromosomes, affecting the number and structure. A cell can rejoin the ends of a broken chromosome but, if there are two breaks close enough together in space and time, the broken ends from one break may join incorrectly with those from another. This can cause translocations, inversions, rings, and other types of structural rearrangement.[8] Radiation is not the only mechanism by which such changes can occur. Spontaneous mutations and nonradiation-induced mutations have been observed.

The mutated genes from one parent can then be passed on to offspring. They typically have no effect on the offspring as long as the genes from the other parent are not mutated in the same way. However, the genes stay in the body of the offspring and are passed on to following generations. If they meet similar genes when reproducing, they would then become present in the characteristics of the offspring.[9]

There is no evidence that there are radiation levels below which chromosomes are not affected, but the number of occurrences drops dramatically at lower levels of radiation.[12]

# Health Risks

Risk can be defined, in general, as the probability or chance of injury, illness, or death resulting from some activity. However, the perception of risk is affected by how one views the probability, severity, and the benefits gained from accepting the risk.
Perhaps the most useful unit for comparing health risks is the average number of days of life expectancy lost each time one performs an activity that includes a health risk. Estimates are calculated by looking at a large number of people, recording their ages at death from apparent causes, and estimating the number of days of life lost as a result of early deaths. The total number of days of life lost is then averaged over the total group observed.

| Health Risk[13] | Average Days Lost |
|---|---|
| Smoking 20 cigarettes/day | 2,370 (6.5 years) |
| Overweight (by 20%) | 985 (2.7 years) |
| All accidents combined | 435 (1.2 years) |
| Auto accidents | 200 |
| Alcohol consumption (U.S. average) | 130 |
| Home Accidents | 95 |
| Drowning | 41 |
| Natural background radiation, | 8 |
| Medical diagnostic x-rays (U.S.average) | 6 |
| All catastrophes (earthquake, e.g.) | 3.5 |
| 1 rem (1,000 millirem) | 1 |
| 1 rem/year for 30 years | 30 |

| Individual Action | Minutes Life Expectancy Lost |
|---|---|
| Smoking a cigarette | 10 |
| Calorie-rich dessert | 50 |
| Non-diet soft drink | 15 |
| Diet soft drink (containing saccharin) | 0.15 |
| Crossing a street | 0.4 |
| Extra driving | 0.4/mile |
| Not fastening seat belt | 0.1/mile |
| 1 mrem of radiation | 1.5 |

Several studies have compared the projected lower life expectancy resulting from exposure to radiation with other health risks. Some representative numbers are presented below.

In decision making, one should consider the risk in each action. The risk of crossing a street is based on pedestrian fatalities and the assumption that the average person crosses five streets per day. It may be noted that smoking a cigarette has the risk equal to receiving 7 mrem of radiation, and an overweight person eating a pie a-la-mode runs a risk equal to that of receiving 35 mrem.[13]

## SUMMARY

Atoms have two basic parts: the nucleus, a mass of protons and neutrons, and the electrons. Since ordinary matter is electrically neutral there must be an equal number of positively charged protons and negatively charged electrons in the atom. When the nucleus of an atom spontaneously decays by "throwing off" a particle and/or additional energy, we refer to this as radioactivity. Therefore, radiation refers to the energy that is released from this decay in the form of alpha particles, beta particles, or gamma rays. The biological effects on humans of high-level ionizing radiation can be severe, but most people receive such low levels that the effects, if any at all, cannot be measured.

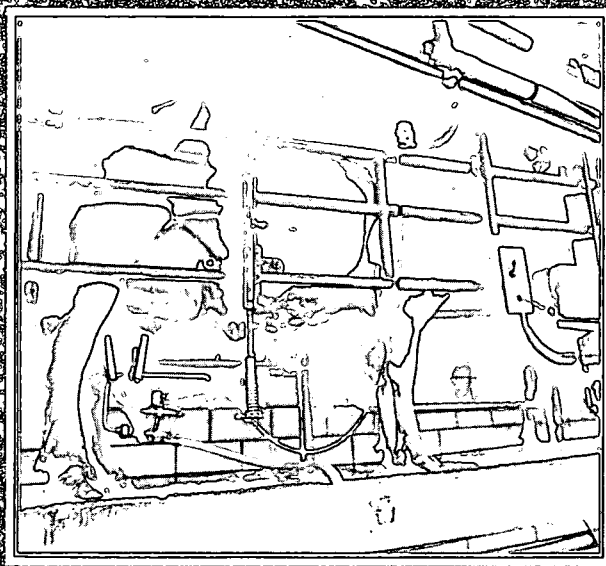
We use the term *curie* as a measure of the activity of a radioactive substance and the term *rem* to express the amount of dose a person receives when exposed to radiation. *Dose* is defined in four different ways: organ dose, effective dose, committed effective dose, and whole body dose.

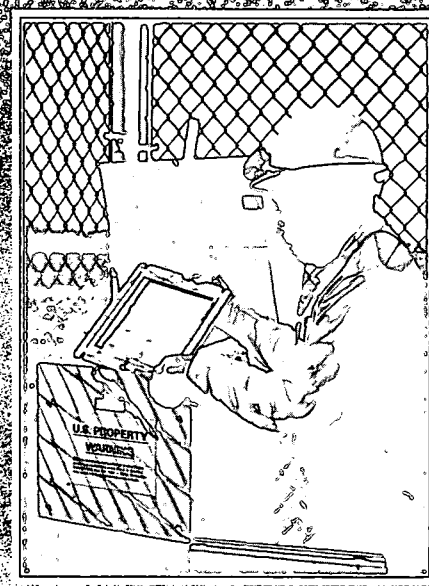
These terms apply to more than just the radiation that facilities like the FMPC produce. We are constantly being exposed to low levels of radiation produced by everyday things such as the earth, a television set, or the sun. This we call background radiation. The effects of the radiation that we are exposed to can be categorized into two types: somatic and genetic. Those people exposed to high levels of radiation undoubtedly face a greater immediate risk of illness, cancer, or death, but scientists are unable to determine whether an increase in low-level radiation increases the number of radiation effects.

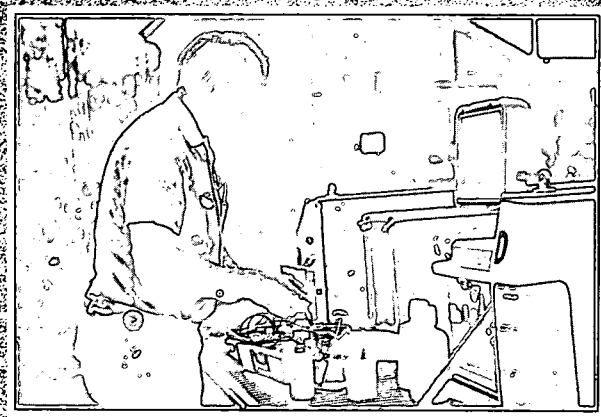
The FMPC environmental monitoring data are presented in the next chapter. Along with this information are descriptions of the methods used to gather data. Using this information and a basic understanding of radiation, we can proceed to Chapter Four for a discussion of the estimated radiation doses to which the people at and around the FMPC might be exposed and how these results were calculated.

# CHAPTER 3

# Results of the FMPC Environmental Monitoring Program for 1989





CHAPTER THREE

# Results of the FMPC Environmental Monitoring Program for 1989

In order to gain a detailed understanding of the effects of production and storage operations on the surrounding environment, the FMPC collects samples of air, water, soil, and other media as one way to measure the amounts of various radioactive and nonradioactive materials that leave the site. The results of the measurements serve several purposes: to determine if the FMPC complies with applicable environmental standards and guidelines, to assess the site's impact on the surrounding area, and to estimate radiation doses to the population.

Overall, these measurements indicate that FMPC emissions and discharges as well as concentrations of radioactive and nonradioactive materials present in the surrounding environment were well below applicable standards and guidelines established by federal and state laws.

This chapter presents the environmental monitoring data collected during 1989 and describes the methods used to collect the samples. Oftentimes, data from 1987 and 1988 are presented for comparison to 1989 data.

The chapter is divided into three major sections. The first section focuses on the air pathway and includes discussions on data collected at the air monitoring stations, radon monitoring locations, and the nonradioactive derived data for Boiler Plant emissions. Results from sampling the soil and grass, produce, and milk segments of the air pathway are also reported.

The second major section of this chapter centers on one part of the liquid pathway. The FMPC samples the liquid effluent to determine the concentration of radionuclides discharged to the Great Miami River and to comply with National Pollutant Discharge Elimination System requirements. Also sampled are water, fish, and sediment from the Great Miami River and water and sediment from Paddy's Run.

The last section of this chapter discusses the sampling of a large component of the liquid pathway: groundwater. In addition to presenting the results from 1989 sampling, this section discusses how the groundwater monitoring program has been evolving and the plans to refine the program as data continue to be evaluated.

# Air Pathways

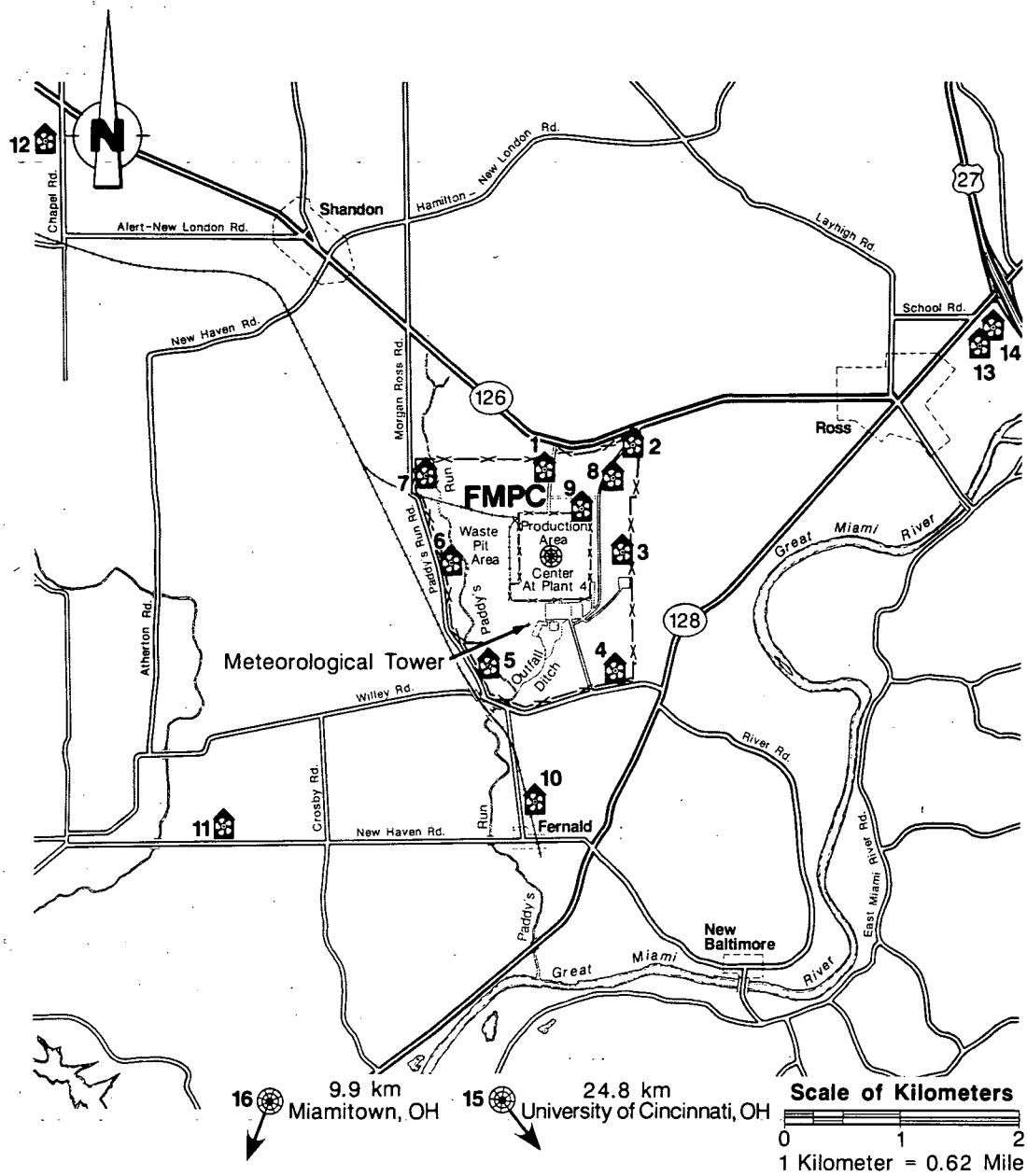
As discussed in Chapter One, the largest overall potential source of radiation exposure to the public from the operation of the FMPC is via the air pathway. FMPC production operations generate airborne radioactive particulates. Ventilation and air-filtration systems, such as dust collectors, reduce employee exposure to these particles and also controls the amounts released into the environment.

In addition to breathing dust particles that could be contaminated, one could be exposed to contaminants which are deposited from the air and introduced to the human food chain through soil, grass, produce, and milk. This section describes the various sampling programs in place at the FMPC to monitor these media for radioactive and nonradioactive parameters.

## *1989 Air Monitoring Activities*

In order to provide accurate information about particulate concentrations in the air, FMPC operates 16 continuous, high-volume air monitoring stations (AMS). The locations for the air monitoring stations, as shown in Figure 9, were selected for several reasons:

- AMS 1 through 7 provide data at the FMPC fenceline because this is where the public has closest access to the site and guidelines for offsite exposure take affect;
- AMS 8 and 9 are in the prevailing wind direction at the FMPC. They were added in the northeast quadrant of the production area in 1986 based on a computer model that predicted the areas where the highest ground-level concentrations of airborne uranium from FMPC operations would be found. AMS 13 and 14 are also located in the same quadrant but further from the site (Ross, Ohio);
- AMS 15 and 16 were installed in 1989 to increase background data — AMS 15 is located near the University of Cincinnati in Corryville, Ohio; AMS 16 is located in Miamitown, Ohio;
- AMS 10, 11, and 12 measure radionuclide and particulate concentrations in nearby communities.




## LEGEND

Air Monitoring Location

Distance from Center of Production Area to Sampling Locations off Map

Plant Perimeter

Production Area Perimeter

Figure 9. Air Monitoring Locations

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At each AMS, air is drawn through a 20 cm by 25 cm (8 inch by 10 inch) filter at a rate of about 1 $m^3$/min (about 35 $ft^3$/min). Any changes in flow rate over the sampling period are accounted for by inspecting charts which continuously record flow data.

The filters from the air monitoring stations are collected and analyzed at weekly intervals. They are weighed before and after use to determine the weight of the collected particulates. At the laboratory, technicians store the filters for at least three days after collection to allow for the decay of naturally-occurring, short-lived radionuclides. Next, the filters are dissolved in acid and the solutions analyzed for uranium concentration and beta activity. A portion of each of these solutions is retained to provide a yearly composite which is then analyzed for trace radionuclides such as isotopes of radium, neptunium, plutonium, and thorium. The next section discusses the results of these analyses.

## Radiological Results from Air Monitoring Stations

The average concentrations of uranium at the seven fenceline (AMS 1 through 7) and seven offsite (AMS 10 through 16) air monitoring stations were all less than 1% of the DOE guideline. Table 1 lists 1989 and 1988 data for uranium and particulate concentrations and gross beta activity. (All tables can be found in Appendix A.) Figures 10, 11, and 12 compare concentrations of these parameters for 1987 through 1989. (The complete set of bar charts can be found in Appendix B. Figure 10 is also reproduced on the next page for your convenience.) For 1989, all air monitoring stations recorded lower average airborne uranium concentrations than in 1988.

Although some concentrations of trace radionuclides were higher in 1989 than in 1988, the highest concentration as reported in Table 2 was less than 1% of the DOE guideline and the general trend was downward. Concentrations of airborne radionuclides for 1987 through 1989 are presented in Figures 13 through 17 in Appendix B.

## Nonradiological Air Monitoring Results

The FMPC estimated nonradioactive pollutants including sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), airborne dust (total

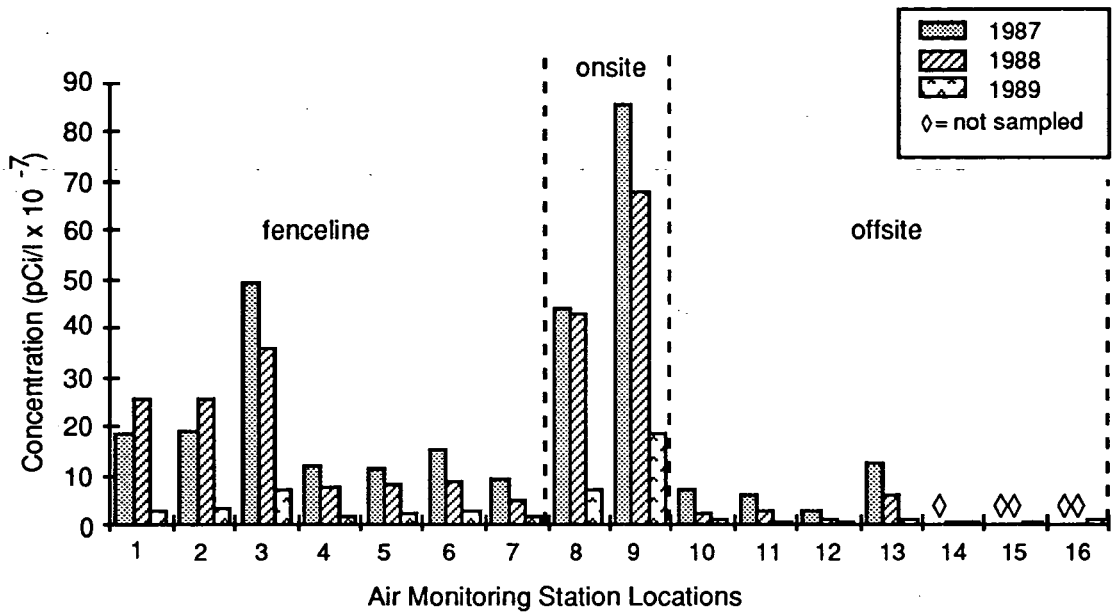


Figure 10. Average Uranium Concentrations in Air, 1987 to 1989

suspended particulates), and the shade or density of emissions from the coal-fired boilers. Shade or density is also called opacity and is a measure of how much light is blocked by particulate emissions.

Sulfur dioxide ($SO_2$) emissions may not exceed 0.9 kg (2 pounds) per million BTU input for each of the two coal-fired boilers at the FMPC.[14] The FMPC checks the sulfur content and heat content of the coal on a regular basis. Sulfur dioxide emissions are calculated according to methods and procedures in Ohio Administrative Code rules.[15] This limit could be exceeded if the FMPC uses coal containing 1.3% or greater sulfur. The FMPC has been using coal containing less than 1% sulfur for a number of years to ensure that $SO_2$ emission limits are not exceeded.

The State of Ohio has not established $NO_x$ emission limits for FMPC industrial process sources since the site is located in a region of the state which is exempt from such limits. The $NO_x$ emissions from the Boiler Plant for 1989 were 157,000 kg (346,000 pounds).

At the FMPC, electrostatic precipitators control particulate emissions from the steam-generation plant. The emissions from the two FMPC coal-fired boilers were continuously monitored by instruments designed to measure opacity. During 1989, the boilers operated 12,401 hours and 124,010 measurements were made

during six-minute periods. Only 18 of these measurements failed to meet the opacity standard. Results of all 1989 opacity measurements were reported to Southwestern Ohio Air Pollution Control Agency (SWOAPCA). Particulate emissions from the Boiler Plant were estimated to be 12,700 kg (27,900 pounds) for 1989, and were based on emission factors developed from stack testing in 1988.

The 1989 results of the analysis of average total suspended particulate concentrations from AMS 1 through 7 ranged from 31.7 $\mu g/m^3$ at AMS 1 to 39.6 $\mu g/m^3$ at AMS 4 (Table 1; Figure 12). These results are 2% lower on average than for 1988, and are well within National Ambient Air Quality Standards (NAAQS).[16,17]

## *Soil and Grass Sampling*

At the FMPC, soil and grass samples indicate concentrations of uranium and fluoride which may have been deposited on the ground from the air. The FMPC analyzed grass samples for fluoride as well as uranium because anhydrous hydrogen fluoride and magnesium fluoride had been part of the production process.

### Soil Sampling Results

The FMPC increased the number of soil samples to 30 in 1989 from 20 in 1988 (Figure 18). The soil samples were taken from undisturbed plots to determine if there were any above-background uranium concentrations. The samples were taken at two depths, 0-5 cm (0-2 in) and 5-10 cm (2-4 in). Care was taken to exclude grass from the samples.

No DOE or USEPA guidelines or standards have been established for most soil radionuclides including uranium. For the purposes of comparison, naturally-occurring uranium-238 concentrations in Ohio range from about 0.6 pCi/g (0.02 Bq/g) to 2.2 pCi/g (0.08 Bq/g).[18] Total uranium activity is about twice this amount since the two major isotopes of uranium, uranium-238 and -234, occur together naturally in soil.

A soil study is proposed for 1990 to determine the natural radioactive background in soil near the FMPC. This study will enable the FMPC to better evaluate the significance of the uranium concentrations in soil samples collected for the Environmental

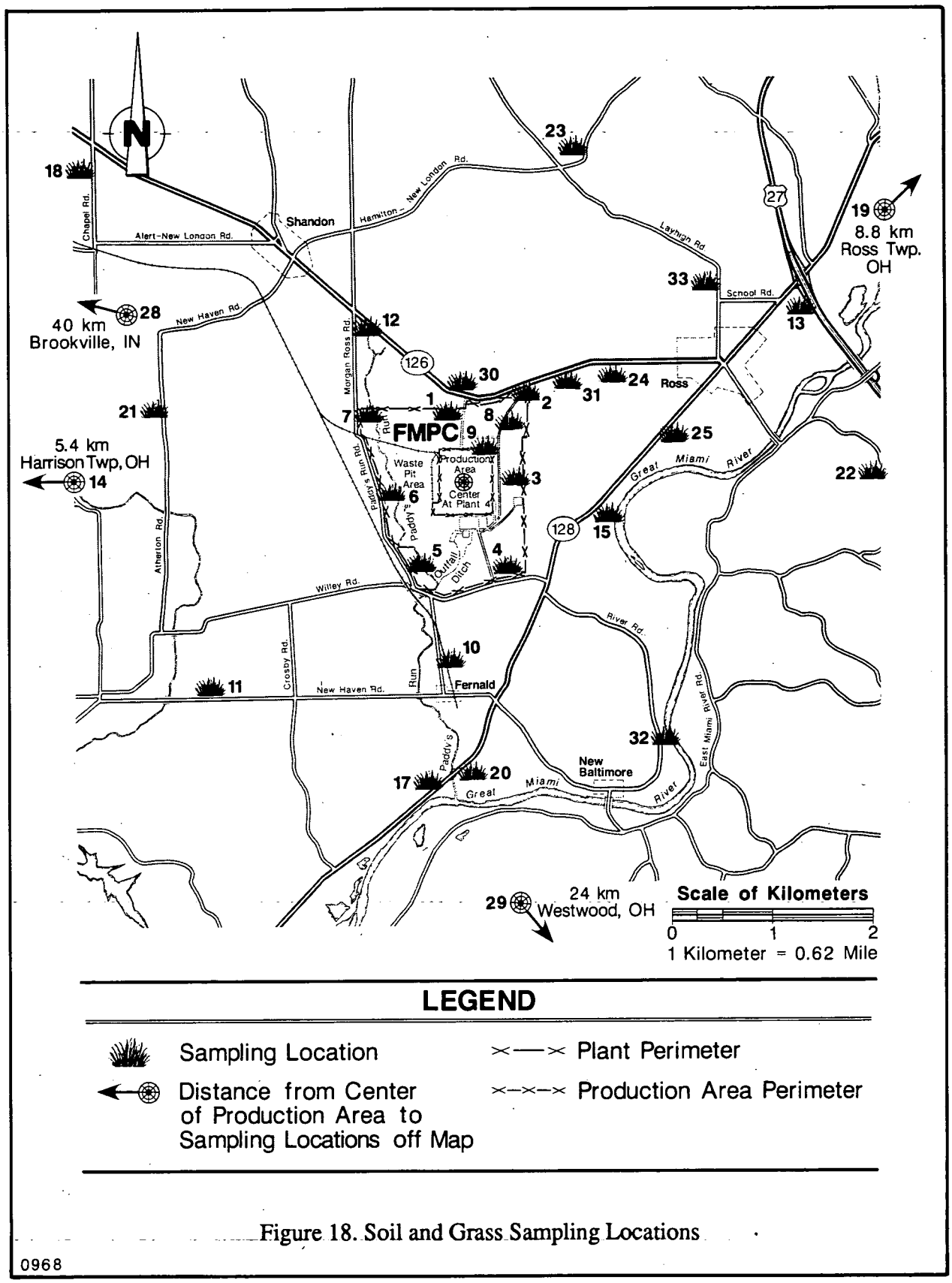


Figure 18. Soil and Grass Sampling Locations

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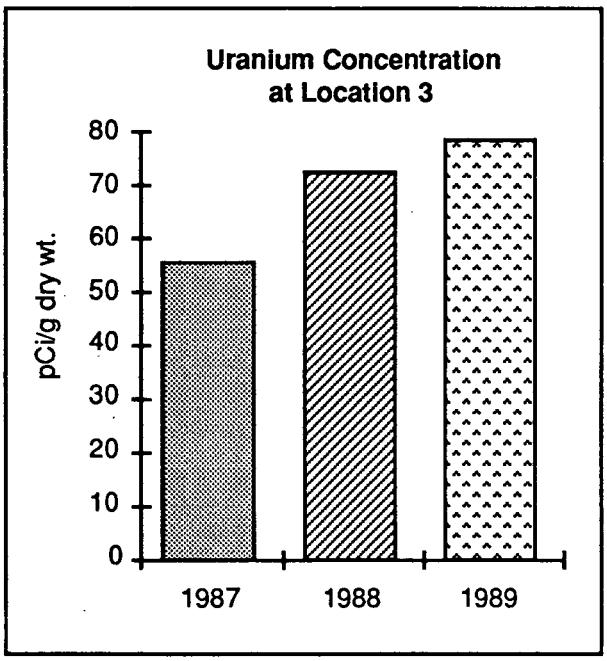
Monitoring Program. In addition, the Remedial Investigation/ Feasibility Study is conducting an extensive survey to determine uranium concentration in onsite soils. In fact, one of the areas from which the RI/FS team collected soil samples was the site of the incinerator that operated near the Sewage Treatment Plant. The data indicate that the uranium concentrations are above background levels. An action to remove this soil is being planned.

Environmental Monitoring personnel have collected soil samples in this area (location 3 in Figure 18) for a number of years and the results have been published in Environmental Monitoring Reports. The sample collected in 1989 at location 3 had the highest uranium concentration of all samples for the Environmental Monitoring Program. Elevated uranium concentrations have been observed at this location for the past several years.

The uranium concentration in the soil samples taken along the fenceline and at AMS 8 & 9 ranged from 3.1 to 79 pCi/g dry wt (0.11 to 2.9 Bq/g dry wt) at the 0-5 cm depth (Table 3).




The uranium concentration in offsite samples ranged from 2.4 to 15 pCi/g dry wt (0.09 to 0.56 Bq/g dry wt). The uranium concentrations in 11 of the offsite samples were above background. One of the 11 was a control sample (location 29 in Westwood, Ohio, a suburb of Cincinnati and 24 km [15 miles] from the center of the site). The uranium concentration at location 29 was 8.0 ± 2.7 pCi/g. When the sampling and analytical uncertainties are considered, the uranium concentrations at three of the remaining 10 locations are within background range.

## Grass Sampling Results

Samples of grass were collected at the same locations as soil. Each grass sample was a composite of at least three subsamples clipped near ground level from a 50 cm (20 inch) diameter circle. The grass samples, which weighed about 500 grams (wet weight), were air-dried and analyzed for uranium and fluoride.

Table 3 also reports the uranium concentration in onsite and offsite grass samples:

- Onsite results ranged from <0.01 to 2.9 pCi/g dry weight (< 0.00037 to 0.11 Bq/g dry weight)
- Offsite results ranged from 0.01 to 0.08 pCi/g dry weight (0.00037 to 0.0030 Bq/g dry weight).

Standards have not been established for uranium in grass; however, the data for 1989 are consistent with results reported in previous years.

Fluoride concentrations in the grass samples collected at AMS 1 - 9 were all less than 2.0 µg/g except AMS 9 which was 15 µg/g or 15 ppm (Table 3). Since the state of Ohio does not have a standard for fluoride in grass, the Kentucky standard of 80 ppm was used for comparison. The average fluoride concentration in grass was less than 3.4 ppm in 1989, which was less than 5% of the Kentucky standard. In fact, the highest fluoride concentration in the grass samples collected offsite was reported as 12 ppm. This is just 15% of the Kentucky standard. Since production has been suspended and fluoride concentrations have consistently been below the Kentucky standard, fluoride analysis will be discontinued after 1990.

## Produce Sampling Results

Naturally-occurring radionuclides present in fertilizers and soil may be taken up by plants through their root systems and incorporated in their edible portions and eaten by humans or animals. To see if FMPC operations may have increased uranium concentrations in produce, Environmental Monitoring personnel sampled produce (and soil, where possible) from 13 farms and gardens within 3.2 km (2 miles) of the center of the site. As a control measure, the FMPC also collected samples from six farms located between 16 km (10 miles) and 48 km (30 miles) from the site (Figure 19). The types of samples are listed on page 51 along with the number of nearby and control sampling locations.

The results of the produce and soil sampling program are reported in Table 4. The data are limited, but do indicate that the uranium concentration in the produce grown near the FMPC does not differ from the uranium concentration in produce grown on farms more

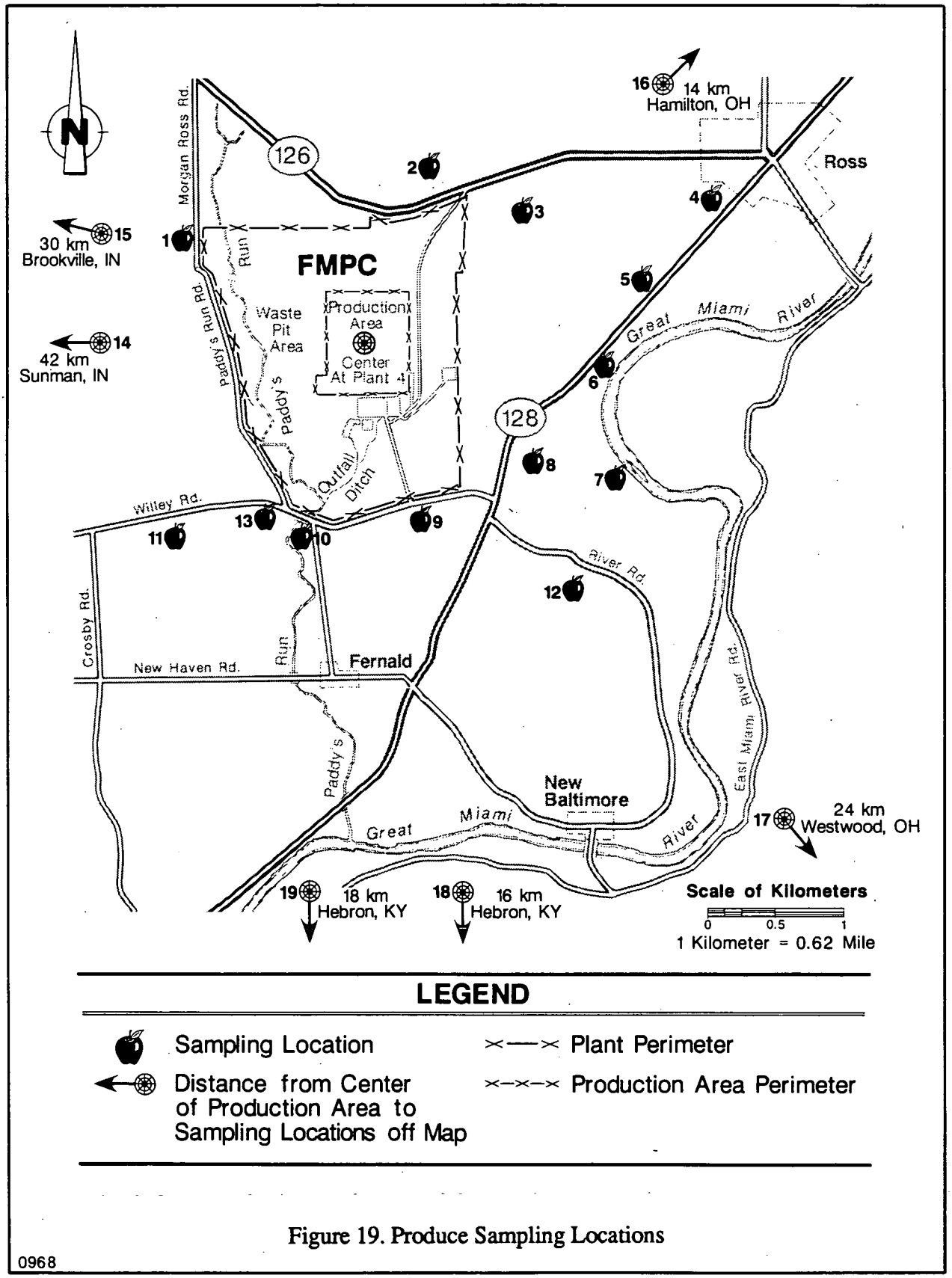



Figure 19. Produce Sampling Locations

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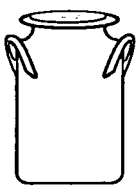
| Item Sampled | Nearby | Control |
|---|---|---|
| Tomatoes | 8 | 3 |
| Corn | 7 | 2 |
| Soybeans | 5 | 1 |
| Potatoes, onions, turnips | 4 | 3 |
| Cabbage and lettuce | 2 | 1 |
| Apples | 1 | 2 |
| Pumpkins and green beans | 1 | 1 |

than 16 km from the site. In fact, the highest uranium concentration, 0.29 pCi/g dry weight (0.01 Bq/g) was found in apples grown in Kentucky, 18 km from the site.

Dose estimates from eating produce grown near the FMPC are calculated and reported in the next chapter.

Uranium concentrations in the soil taken along with produce ranged from 1.4 to 5.9 pCi/g (0.05 to 0.22 Bq/g). These soil data are reported in Table 4. Tomatoes grown at location 2 (uranium concentration in this soil was 5.9 ± 1.8 pCi/g) had the second lowest uranium concentration of all tomatoes sampled.



## *Milk Sampling Results*

Another way by which radiation can reach humans is through the air-to-grass-to-cow-to-milk pathway. Milk is potentially a significant pathway to humans for some radionuclides for several reasons: the relatively large surface area that a cow can graze every day, the rapid transfer of milk from producer to the consumer, and the importance of milk in the diet. Furthermore, cows graze on land immediately adjacent to the FMPC. Therefore, the FMPC collects monthly milk samples and has them analyzed for uranium even though research has shown that uranium is not normally concentrated in cows' milk.

In 1989, the FMPC sampled milk produced by cows grazing on FMPC land adjacent to the site as well as at a control dairy in Indiana about 35 km (22 miles) west of the FMPC. The average uranium concentration present in the milk samples from both locations was below the laboratory's minimum detectable level of 0.7 pCi/l (0.03 Bq/l) for every month but October (Table 5).

From an examination of the uranium in milk results for the last quarter of 1989, it is apparent that the October result for the FMPC dairy is incorrect and was caused by something other than an actual release of uranium to the environment. A very significant and

widespread airborne release of uranium would had to have occurred for the uranium concentration in milk at the adjacent dairy to increase from <0.7 pCi/l to 12.8 pCi/l during one month. Such a release could not have possibly taken place unnoticed and would certainly have been detected by the continuously operating air monitoring stations located around the site. Actually, there were no major airborne uranium releases during 1989. Also, there were no elevated airborne uranium concentrations measured at the onsite (AMS 8 and 9) and fenceline (AMS 1 through 7) air monitoring stations during September or October 1989. In fact, the maximum and average airborne uranium concentrations at AMS 1 through 9 were lower in 1989 than in 1988.

| Year | Number of Samples | Results |
|---|---|---|
| 1983 | 4 | 3 of 4 <0.7 pCi/l |
| 1984 | 5 | all <0.7 pCi/l |
| 1985 | 3 | all <0.7 pCi/l |
| 1986 | 6 | all <0.7 pCi/l |
| 1987 | 12 | all <0.7 pCi/l |
| 1988 | 12 | 11 of 12 <0.7 pCi/l |
| 1989 | 12 | 11 of 12 <0.7 pCi/l |

The FMPC has been reporting the results of milk sampling in the Environmental Monitoring Report since 1983. Of the 54 samples collected from 1983 through 1989, only two samples other than the October 1989 sample were above the detection limit for uranium. Those results were 1.35 pCi/l in 1983 and 1.0 pCi/l in 1988.

Also, if such a significant release of uranium had taken place, the uranium would have remained in the environment and continued to appear in the milk for an extended period. The uranium in the milk would not have quickly increased to 12.8 pCi/l in one month and been absent the following month if the increase had actually been caused by uranium released from the site.

Further evidence that the uranium result for the October milk sample from the adjacent dairy is incorrect is the fact that uranium was also found in the October milk sample collected from the control dairy (Table 5). The control dairy is located 40 km (25 miles) west-southwest of the site and is not affected by FMPC operations. Evidently, the October milk samples from both dairies became contaminated with extraneous uranium either present in the sample containers, or while being transported from the field to the laboratory, or during analysis.

## *The Radon Monitoring Program*

In recent years, the potential hazards associated with high radon concentrations have been receiving increased attention. There are two isotopes of radon that are of interest at the FMPC. The first, commonly called radon, results from the radioactive decay of uranium-238. The second, commonly called thoron, results from the radioactive decay of thorium-232. The FMPC stores materials that produce radon and thoron. Radium-226, the immediate precursor of radon, is found in the material stored in the K-65 Silos, silo 3, and the waste pits. Thorium-228, a precursor of thoron, is found in the material stored in the thorium warehouses. In general, radon, which has a half-life of 3.8 days, has a greater potential for contributing to offsite radiation dose than thoron, which has a half-life of less than one minute.

To determine radon concentrations, the FMPC collected data by monitoring 21 locations along the FMPC fenceline during 1989. In addition, there were 16 radon monitoring locations immediately adjacent to the K-65 Silos, four monitoring locations onsite at various distances from the silos, and nine offsite locations (Figures 20 and 21).

The nine offsite locations were: four at offsite air monitoring stations; three positioned outdoors at nearby residences; and two control locations more than 20 km (12 miles) from the FMPC in the two least prevalent wind directions. These last two locations were monitored in order to measure background concentrations of radon. The program also includes continuous radon monitors which were installed at four locations along the K-65 exclusion fence. These monitors are not used for perimeter fenceline dose calculations, but will provide data for estimating doses for those working near the K-65 silos.

The two new air monitoring stations, AMS 15 & AMS 16, placed in service in late 1989 at background locations in Cincinnati and Miamitown, included radon detectors. In 1990, the radon data from these locations will double the number of background locations monitored for radon to four.

Each fenceline location contains two, three, or six alpha-track-type radon detectors in weatherproof housing. An alpha-track radon detector is a passive, long-term device for integrating radon

concentrations in air by permanently recording the tracks of alpha particles being emitted from radon and its decay products. The detectors are changed quarterly and sent to the supplier for analysis. A summary of results is presented in Table 6. The 1989 average fenceline concentrations are somewhat lower than those in 1987 and 1988. In addition, the 1989 data had better precision than previous years with an average standard deviation of ± 0.15 pCi/l (± 0.006 Bq/l) compared to ± 0.60 pCi/l and ± 0.62 pCi/l for 1988 and 1987, respectively. Since the FMPC radon program did not change significantly during those years, the improvement in precision is attributed to improvements in analytical performance by the supplier.

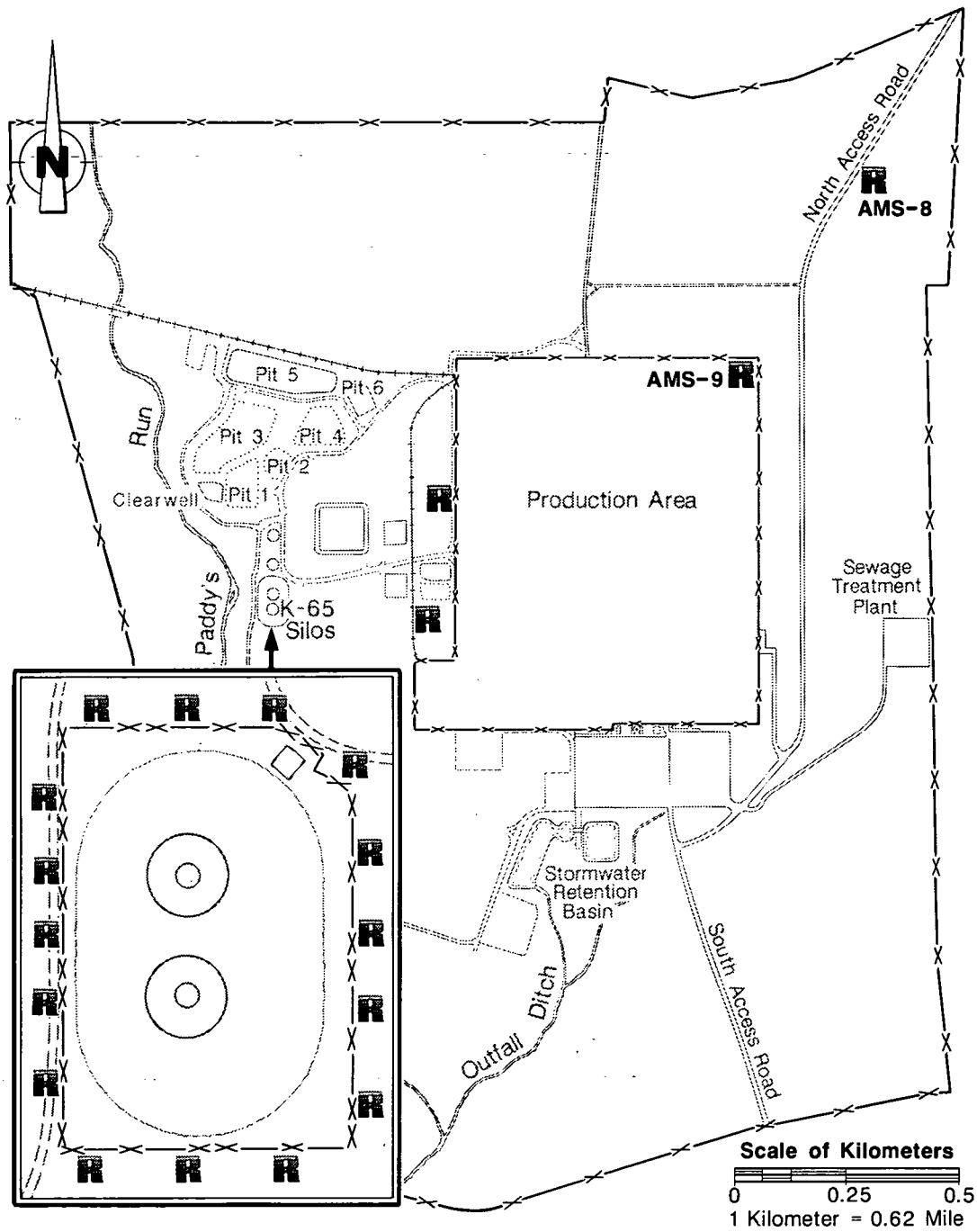
For each quarter of the year, the average radon concentration at each location was computed from the results for all of the detectors at that location. At year's end, the average of the four quarterly concentrations was computed; these annual averages are presented in Table 6.

Also presented in Table 6 is the average of all 21 fenceline monitoring locations for 1989, the average of the two background locations for 1989, and the average net radon concentration at the fenceline for 1989. Included with this data are the standard deviations at the 68% confidence level (one sigma). The net concentration of 0.24 ± 0.15 pCi/l (0.009 ± 0.006 Bq/l) indicated that the concentrations measured at the fenceline were well within DOE guidelines which specify that emissions of radon to uncontrolled areas must be at average concentrations less than 3.0 pCi/l (0.11 Bq/l) above background concentrations.

The average fenceline concentration can also be compared to the action level of 4 pCi/l (0.15 Bq/l) recommended by the USEPA for indoor radon concentrations.

As a quality control measure, five detectors of the same type were placed at the same location each quarter. The average standard deviation of the results from this location (location K in Figure 21) in 1989 was ± 41%, which was comparable to 1988 results (± 33%). The precision of both 1989 and 1988 results were much improved over the 1987 average standard deviation of ± 89%.

If the six fenceline locations along Paddy's Run Road closest to the K-65 Silos (FMPC J through O in Figure 21) were averaged for




## LEGEND

Onsite Locations

Plant Perimeter

K-65 Silos Area Perimeter

Production Area Perimeter

Figure 20. Onsite Radon Monitoring Locations

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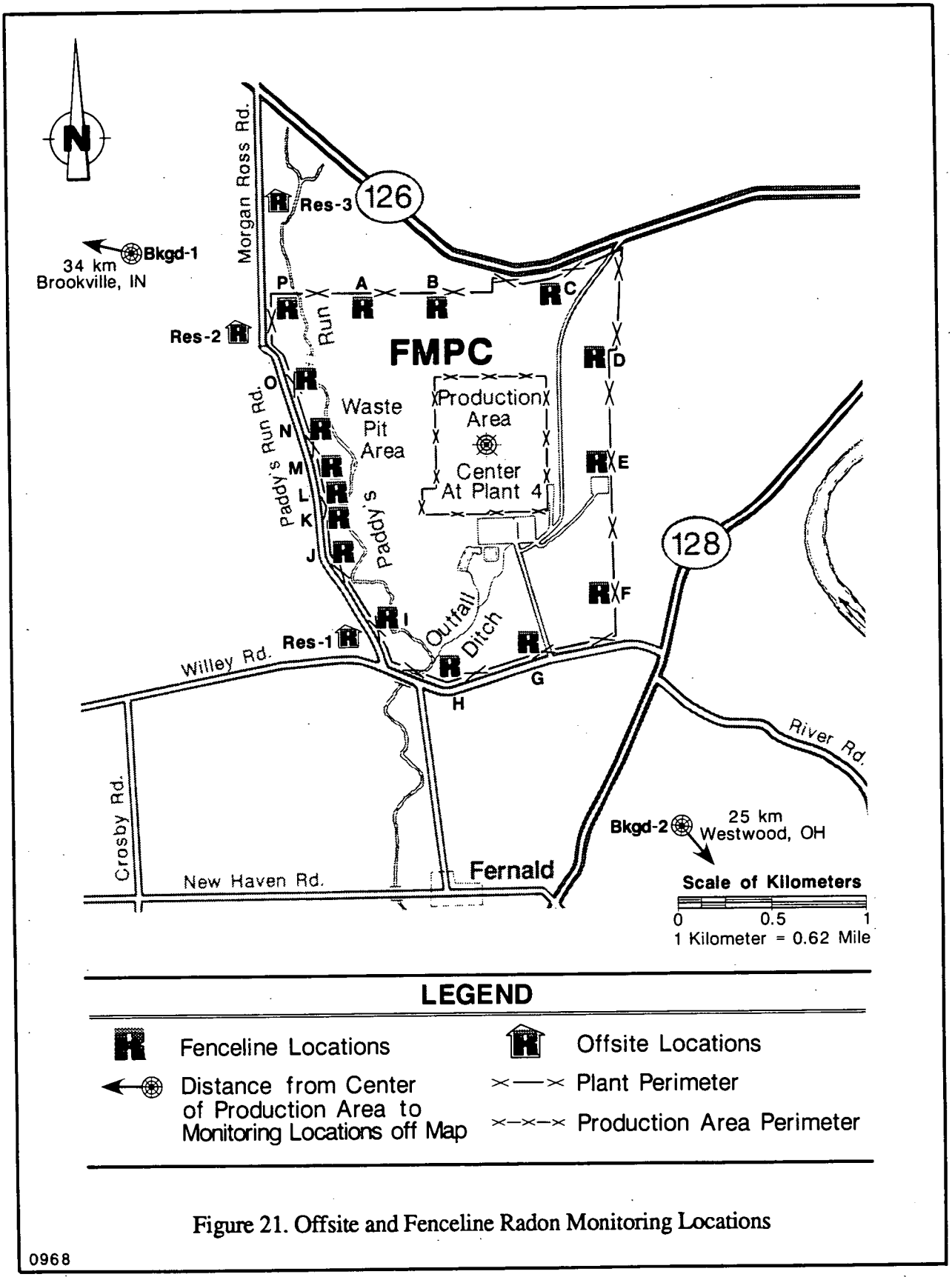


Figure 21. Offsite and Fenceline Radon Monitoring Locations

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the year, the average radon concentration at those locations, 0.78 ± 0.15 pCi/l (0.029 ± 0.006 Bq/l), would fall within the DOE guideline of 3 pCi/l above background. The average net above-background radon concentration at these locations was 0.28 pCi/l (0.010 Bq/l), which was 10% of the DOE guideline. Although the data indicated that the west fenceline concentrations were above background, those concentrations are less than the average indoor radon concentration for houses in the United States as reported by the USEPA.

## SUMMARY OF AIR PATHWAY

In general, air pathway results for 1989 were markedly lower than comparable results for 1988. Fenceline uranium concentrations were lower on average by 75%. Fenceline radon concentrations were also lower and the reported analytical results were more precise than comparable 1988 results. Fenceline concentrations of airborne uranium and radon were 1% and 10%, respectively, of the DOE guidelines. Some onsite and nearby offsite soil samples continue to indicate some impact from airborne deposition from past operations. Milk, produce, and grass samples indicated no measurable contributions via the air pathway from 1989 FMPC operations.

# Liquid Pathways

The FMPC may release radionuclides and chemicals through the liquid pathway as well as through the air pathway. The FMPC investigates the effects of past and current operations on the liquid pathway by sampling the Great Miami River, Paddy's Run, and groundwater. Contaminants in these bodies of water may have originated from the FMPC or other sources. They can be present in liquid effluent discharges and uncontrolled stormwater runoff.

During 1989, the FMPC discharged an average of 2.3 million liters (600,000 gallons) of effluent into the Great Miami River each day. This effluent included process wastewater, sanitary wastewater, wastewater from the water treatment plant and coal pile runoff, and controlled stormwater runoff. This water was sampled continuously before it was discharged and was analyzed for uranium and other radionuclides that could have been in FMPC effluent. In addition, daily grab samples (a grab sample is a single sample taken at one time) were taken from the Great Miami River both upstream and downstream from the point where the FMPC effluent enters the river.

There are two routes by which the liquid discharge from the FMPC can enter Paddy's Run. The first is through the overflow of the Stormwater Retention Basin (SWRB), which is designed to contain stormwater that falls on certain areas of the site. If there is a very large storm, or a series of smaller storms, the SWRB can reach capacity, and the overflow would be discharged to Paddy's Run via the outfall ditch. In 1989, there were two overflows totaling about 2.3 million liters (600,000 gallons).

A second route is via uncontrolled stormwater runoff directly to Paddy's Run. This primarily comes from the nonproduction areas of the FMPC. A project that is underway to collect additional stormwater runoff from the waste pit area and then pump it to the Great Miami River is discussed in a section of the Remedial Investigation and Feasibility Study in Chapter Seven. Paddy's Run water was sampled weekly at six locations both above and below the FMPC.

The third segment of the liquid pathway is groundwater. The FMPC is extensively studying the groundwater at the site and in nearby areas to determine the extent and movement of contamination

caused by FMPC operations. Groundwater monitoring is discussed in detail later in the chapter.

The rest of this chapter includes a discussion of how the FMPC monitors its liquid effluents, surface water runoff, sediment, and fish for both radioactive and nonradioactive parameters as appropriate.

## Sampling FMPC Liquid Effluents

Liquid effluents discharged by the FMPC directly into the Great Miami River originate from four sources: process wastewater, controlled stormwater runoff, sanitary wastewater, and wastewater from the water treatment plant and coal pile runoff. Figure 22 illustrates the flow of the effluents and where they are treated before discharge to the river.

The first source of liquid effluent is process wastewater. All process wastewater is collected and treated in various facilities throughout the site to reduce radioactive and chemical contaminants. After the process wastewater is treated in the Biodenitrification Facility (BDN) to reduce nitrates, it is combined with the sanitary sewage (the second source of liquid effluent) for processing at the Sewage Treatment Plant to remove biological contaminants. The combined treated effluent discharges to Manhole-175 where it flows by gravity through a buried pipeline to the Great Miami River.

The third source of liquid effluent is stormwater. This effluent is produced from rain falling in the waste pit area and production area shown in Figure 23. While some contaminated stormwater is uncontrolled and runs directly offsite, stormwater which contains the major quantities of uranium and other pollutants is controlled by collection and treatment systems.

Stormwater runoff that is controlled in the waste pit area is sent either directly to the Biodenitrification Surge Lagoon (BSL) or is collected in the clearwell from where it is pumped to the BSL. At the BSL, the runoff mixes with production wastewater and the combined liquid effluent is treated in the BDN. Stormwater runoff from the production area is collected by a network of storm sewers which connect at Manhole-34. A small dam at Manhole-34 allows the collected water to be diverted to the Storm Sewer Lift Station

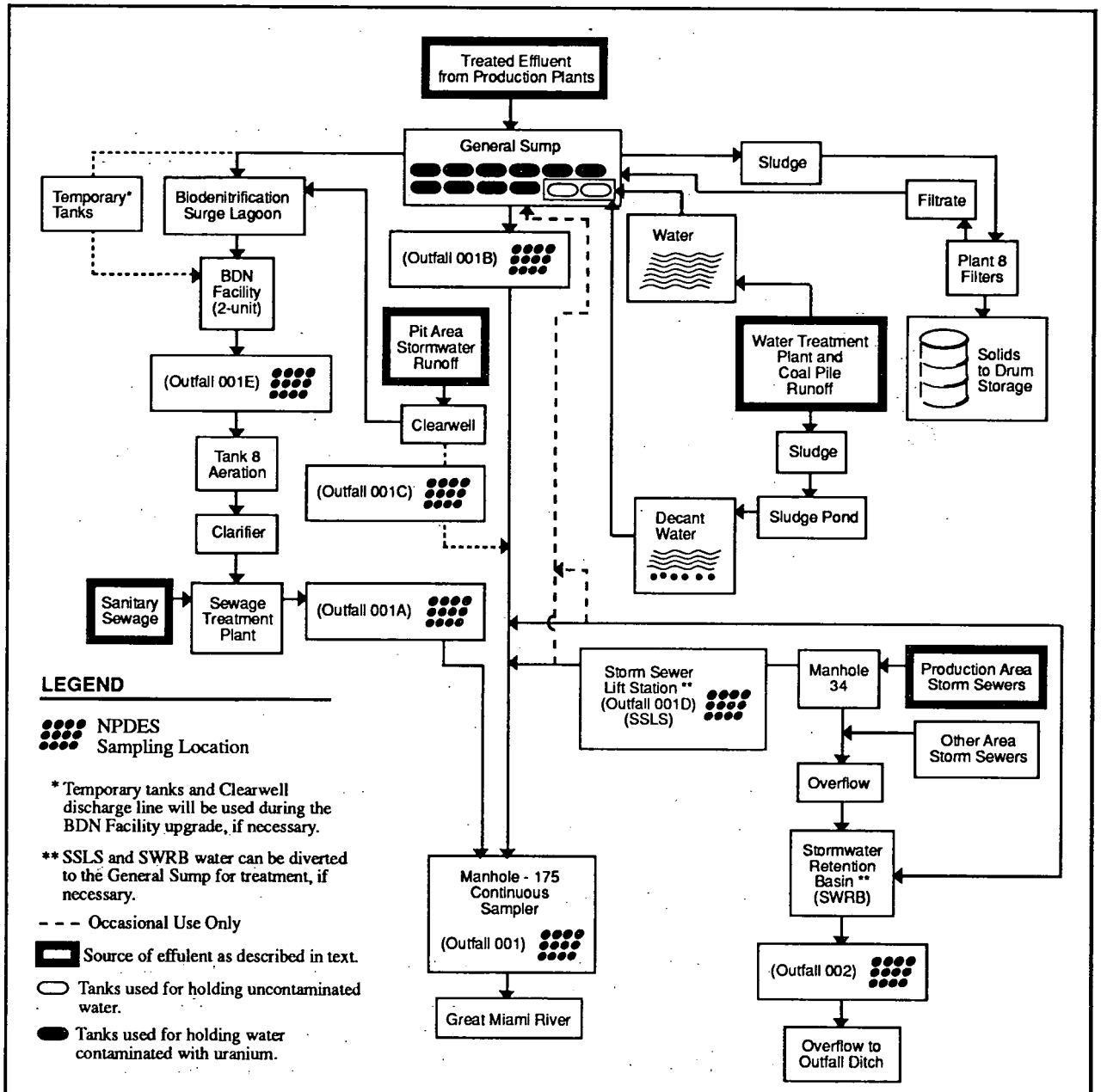
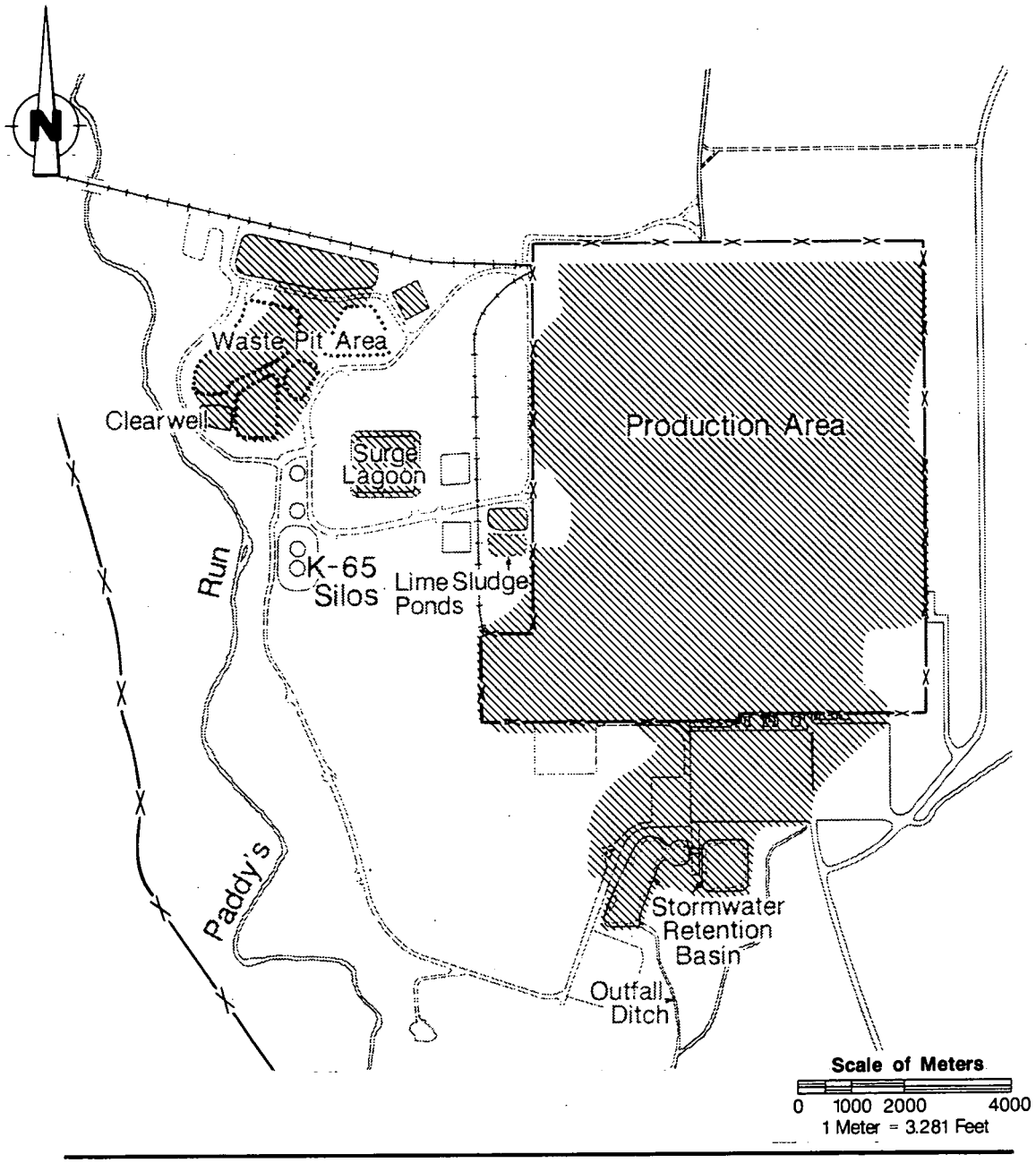



Figure 22. FMPC Liquid Waste Flow Diagram

(SSLS) during dry weather. The SSLS is pumped to Manhole-175 and then to the Great Miami River.

When it rains, the pumping capacity of the SSLS may be exceeded. On such occasions, the excess runoff bypasses the SSLS and flows by gravity to the Stormwater Retention Basin (SWRB). After it combines with water collected downstream of Manhole-34 and the solids settle for a minimum of 24 hours, the process of pumping the




## LEGEND

Shaded Areas are Collected and Eventually Discharged to the Great Miami River

Plant Perimeter

Production Area Perimeter

Figure 23. Area of Controlled Stormwater Runoff

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clarified stormwater runoff from the SWRB to Manhole-175 begins. This process continues for several days.

The fourth source of liquid effluent originates at the water treatment plant. There, groundwater is treated for use as a water supply to the FMPC and the sludge that is produced is sent to the General Sump. (The General Sump is the common name for a series of tanks that are used for settling solids present in the liquid effluents.) At the General Sump, solids are separated from the liquid. Then the sludge is sent to the sludge pond for several days, and the clarified liquid is returned to the General Sump and eventually to Manhole-175. Stormwater runoff from the coal pile, after collecting and settling in a holding pond, is also sent to the General Sump and handled in a similar manner.

In summary, FMPC controls liquid effluents, including process wastewater, wastewater from the water treatment plant, sanitary wastewater, and some stormwater runoff – all of which eventually enter Manhole-175. There the effluents combine and mix to form a single liquid from which a representative sample can be taken before the effluent flows to the Great Miami River.

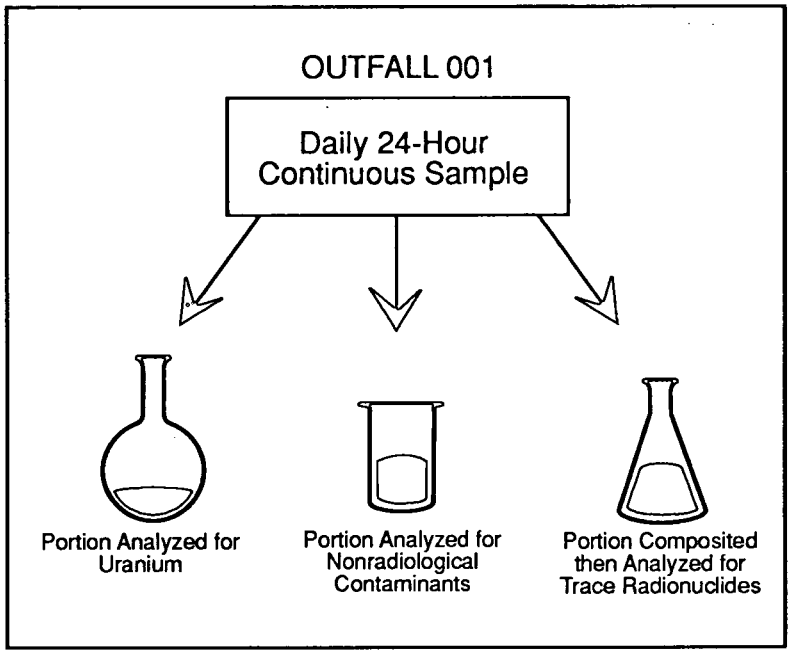
Sampling of the mixed effluent is accomplished with a flow-proportional sampler, a continuously operating device which removes a varying amount of the effluent in proportion to the volume of flow to the river. After every 24 hours of operation, the collected liquid is removed from the automatic sampler to provide a daily flow-weighted sample of the effluent. Portions of this continuous sample are analyzed for radionuclides and for nonradioactive contaminants.

**Radionuclide Discharges In Liquid Effluents**

A portion of each daily sample of effluent flowing through Manhole-175 (Outfall 001) was analyzed to determine the amount of total uranium discharged to the Great Miami River. Portions of all daily samples collected during each month were mixed to form monthly composites which were analyzed to determine the amount discharged of individual uranium isotopes, 12 other radionuclides listed in Table 7, and total plutonium-239 plus plutonium-240. Additionally, cesium-137, ruthenium-106, and strontium-90 analyses were performed on three-month composites prepared from all daily samples collected during each calendar quarter. Composites rather than daily samples were analyzed

because many of the radionuclides were present in only trace amounts and it was not practical nor cost-effective to perform more frequent analysis for them.

Results of the effluent radionuclide analyses are summarized in Table 7. The average concentration and total curies discharged to the Great Miami River during 1989 are listed for each radionuclide. The total curies of the various radionuclides discharged during 1988 are also included for comparisons.




During 1989, 0.52 curie (841 kg) of uranium was discharged to the Great Miami River at Outfall 001. This was a decrease of 5.5% on an activity basis and a reduction of 2.0% on a mass basis in comparison to the 0.55 curie (858 kg) of uranium discharged to the river during 1988. Comparisons of uranium discharges (in curies and in kilograms) at Outfall 001 during 1989 and the two previous years are depicted in Figures 24 and 25.

Although there was an increase in 1989 from 1988 in the total curies of plutonium-239 plus plutonium-240 and thorium-232 discharged at Outfall 001, the average effluent concentration of these radionuclides was only 0.4 and 1.6% respectively of DOE guidelines.
In 1989, the method for calculating the amount of thorium-234 was changed leading to an apparent increase in the amount of this radionuclide discharged. This method, which assumes radioactive equilibrium with the more accurately measured uranium-238, results in the largest reasonable amount of thorium-234 discharged. If the same method had been applied in 1988, the amount of thorium-234 discharged would have been identical for 1988 and 1989.

The amounts of strontium-90, technetium-99, thorium-228, and thorium-230 discharged at Outfall 001 to the Great Miami River were less in 1989 than 1988.

The 1989 average concentration of uranium-234 and uranium-238 in the effluent to the river was 48 and 50% of the DOE guidelines. Of the 16 other radionuclides listed in Table 7, the average effluent concentration of seven were less than 1% and 11 were between 1.2 and 14.7% of the DOE guidelines. However, since there is more than one radionuclide in the effluent, the percentages must be added.[4] For the FMPC in 1989, the sum is greater than 100% of the DOE guideline. The FMPC is designing an advanced wastewater treatment facility, using best available technology, to address the situation.

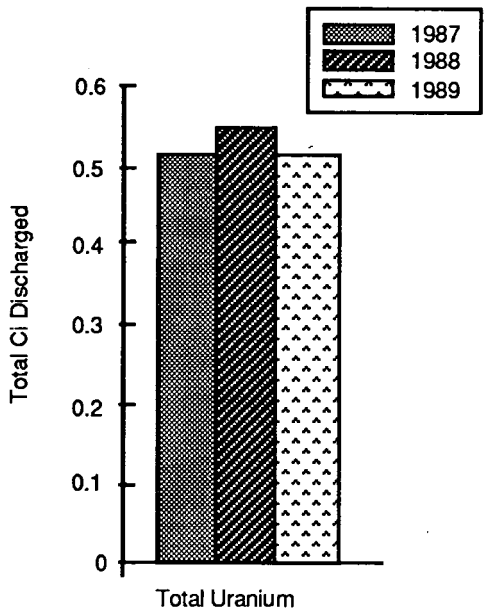



Figure 24. Total Uranium (in Curies) Discharged Through Outfall 001, 1987 to 1989

During two periods of unusually heavy rainfall in 1989, all of the stormwater runoff which entered the SWRB could not be pumped to Manhole-175 for discharge to the river. As a result, 2.3 million liters (600,000 gallons) of stormwater containing 1.0 kg (2.2 pounds) of uranium overflowed into the outfall ditch. Since the SWRB began operating in 1986, the amount of uranium entering the outfall ditch has been substantially reduced.

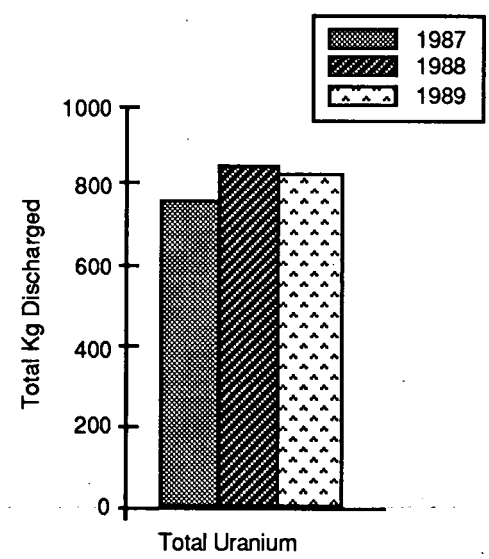
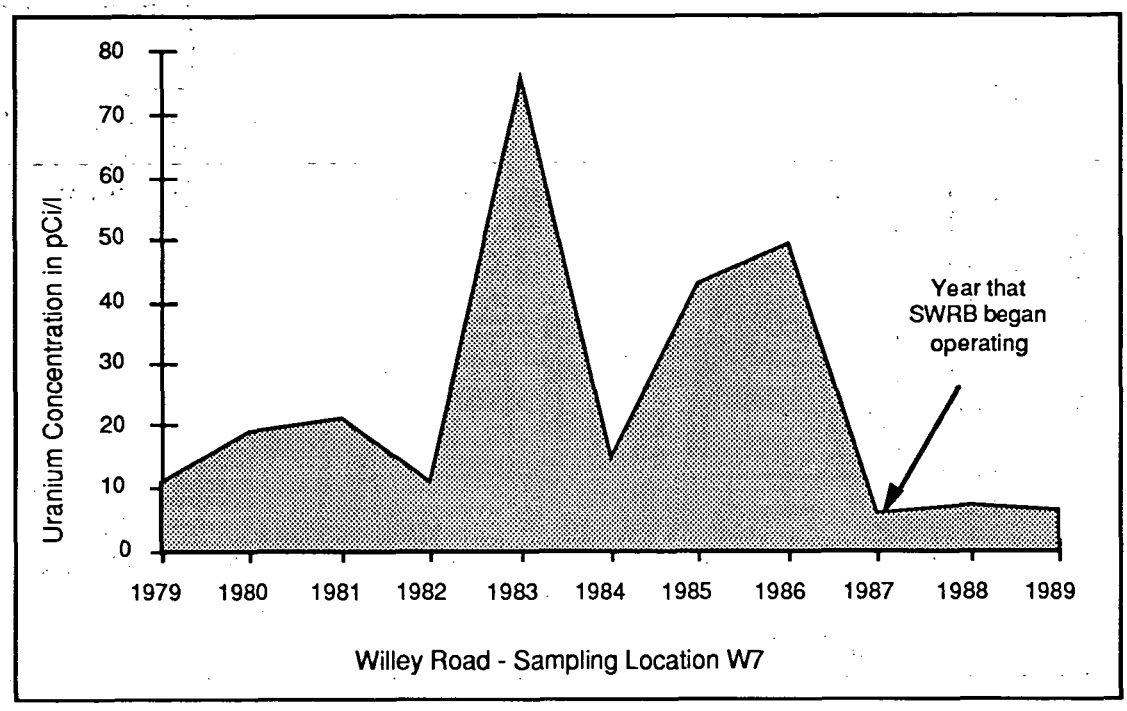



Figure 25. Total Uranium (in Kilograms) Discharged Through Outfall 001, 1987 to 1989




By operating the Stormwater Retention Basin, the FMPC has reduced the amount of uranium discharged into the outfall ditch and Paddy's Run. This is reflected in the decreased average uranium concentration in surface water grab samples collected from Paddy's Run at Willey Road. This is location W7 in Figure 27.

## National Pollutant Discharge Elimination System Compliance Summary for 1989

The NPDES permitting process for the FMPC is under the jurisdiction of the State of Ohio to control the discharge of nonradioactive pollutants to Ohio waters. The permit specifies sampling locations, sampling and reporting schedules, discharge limitations, water quality standards, and other restrictions on FMPC discharges to the Great Miami River and Paddy's Run. Liquid effluent samples collected at the NPDES locations during 1989 indicated that the FMPC met the NPDES daily maximum and monthly average permit limits more than 98% of the time (Table 8). The noncompliances are graphed by month in Figure 26.

There are seven regulated discharge locations which are identified in Figure 22. Two discharges are directly to Ohio waters (001 and 002) and five are internal contributing effluent streams. These

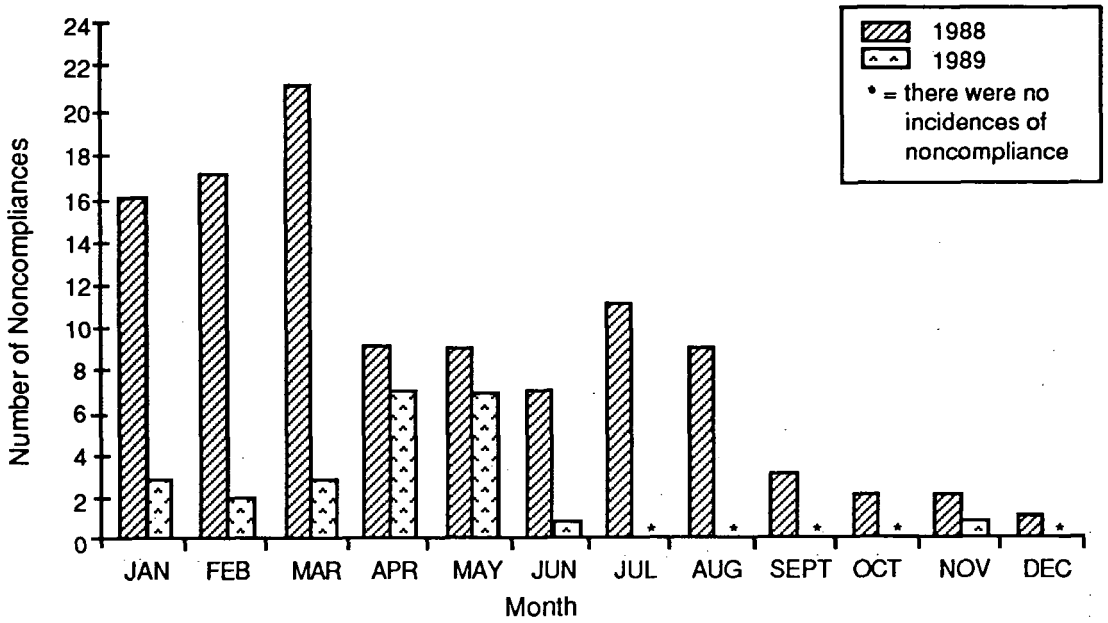



Figure 26. NPDES Noncompliances, 1988 and 1989

discharges were sampled at the frequencies shown in Table 8, and the analytical results were reported monthly to the OEPA.

**Location 001A – The Sewage Treatment Plant**

The FMPC complied 100% of the time with the NPDES concentration limit of milligrams per liter for total suspended solids (TSS) at the Sewage Treatment Plant during 1989. However, the mass limit of kilograms per day for TSS was exceeded eight times. The reasons for the mass noncompliances can be attributed in part to the fact that the TSS mass limits were based on an employment level of 560 and which, at the time the permit was written, were only for the sanitary wastewater discharge. In 1989, employment was about 1,100 (plus several hundred subcontractors), and the process water from the Biodenitrification system was pumped to the STP to remove BOD and TSS.

Furthermore, during the first six months of 1989 the FMPC received near-record rainfall. Controlled stormwater runoff from portions of the FMPC was sent to the STP after treatment in the Biodenitrification facility thus increasing the total amount of effluent that the STP had to treat. The FMPC is upgrading the BDN treatment system, providing separate treatment of the BDN effluent, and will be discharging the effluent directly to Manhole-175. The STP will then treat only sanitary sewage.

**Location 001B - The General Sump**
There were no noncompliances at the General Sump during 1989. Compliance efforts include projects that affect upstream treatment facilities as well as the General Sump itself. Process equipment at Plant 6, Plant 8, Building 13 sumps, and the General Sump will be renovated to best available technology levels. These improvements will enable the FMPC to continue to meet the NPDES discharge limits for TSS, pH, heavy metals and fluorides as presently monitored in the discharge from the General Sump.

**Location 001C - The Clearwell**
The two iron and two TSS noncompliances that occurred at the clearwell in April 1989 were attributed to heavy stormwater runoff. Iron noncompliances had not occurred since before 1985. With pit 5 no longer in service, the discharge from the clearwell has changed from a daily discharge as permitted in 1980 to an intermittent discharge. Therefore, the single daily discharge noncompliances for iron and TSS also resulted in monthly noncompliances for these parameters.

The clearwell noncompliances will be corrected by eliminating the direct discharge of this wastewater to Manhole-175. Upon completion of the Biodenitrification Surge Lagoon liner upgrade project, the clearwell discharge was routed to the BSL for settling as addressed in the BSL permit.

**Location 001D - The Storm Sewer Lift Station**
The Storm Sewer Lift Station (SSLS) had four noncompliances for TSS. The TSS discharge level from the SWRB is not monitored under the 1980 NPDES permit. The FMPC is trying to reduce the amount of TSS in the flow from the SSLS and SWRB to Manhole-175 by enforcing erosion control methods on construction sites, improving effluent monitoring, and operating the SWRB.

**Location 001E - The Biodenitrification Facility**
The discharge from the BDN system was in 100% compliance during 1989. This is largely due to the fact that the Refinery did not operate. The refinery produces about 45% of the nitrates the BDN treats. The expansion of the BDN, coupled with the construction of the high-nitrate storage tank and the BDN Effluent Treatment System, should provide adequate treatment for future operations.

**Location 001 – Manhole-175**
There were five TSS noncompliances at Manhole-175 which occurred from January through August 1989. They can be attributed to three factors:

- An increase in the amount of stormwater discharged to Manhole-175
- Additional solids in runoff from ongoing construction projects
- Changes to the process wastewater treatment system.

Previously, when the stormwater flow exceeded the SSLS pumping capacity, the excess stormwater was discharged to Paddy's Run via the outfall ditch. When the SWRB came on-line in late October 1986, excess stormwater was collected, allowed to settle, then sampled and pumped to Manhole-175. This increased TSS levels at Outfall 001.

**Location 002 – The Outfall Ditch**
Two noncompliances for monthly average TSS were measured at the SWRB overflow. Overflows at Outfall 002 now occur about once or twice a year. The greatest amount discharged in one day during 1989 occurred on March 31. It was above the monthly average for TSS and resulted in a noncompliance since it was the only discharge recorded during the month. The second overflow occurred on April 4, 1989.

Through improved facilities, procedures, practices, and aggressive management of the wastewater program, significant progress has been made during 1989 in NPDES compliance. Only one noncompliance occurred during the second half of 1989 compared to 28 for the same period in 1988.

## *Surface Water Sampling Results*

The FMPC Surface Water Sampling Program measures the effects of two things: the discharge of liquid effluents into the Great Miami River and the effects of uncontrolled stormwater runoff into Paddy's Run. During 1989, surface water was sampled for

radioactive and nonradioactive parameters at the following locations identified in Figure 27:

- Three locations along the Great Miami River (W1 which is upstream from the site, W3, W4).
- Three onsite locations along Paddy's Run (W9, W10, W11)
- Three offsite locations along Paddy's Run (W5 which is upstream from the site, W7, W8).

During the summer, sections of Paddy's Run are often dry which affects the sampling schedule.

Grab samples were collected daily at sampling stations W1 and W3 and weekly when possible at W4 on the river. Each week, one of the daily samples from each location is analyzed fro pH, chloride, fluoride, nitrate, and uranium. Portions of the daily W1 and W3 samples and the weekly W4 samples are combined to form a monthly composite sample which is analyzed for radium-226 and radium-228. Six-month composites, prepared from the individual monthly composites, were analyzed for cesium-137, strontium-90, and technetium-99.

Weekly grab samples were collected if there was flow at the five locations along Paddy's Run: W5, W7, W9, W10, and W11. The samples were analyzed for pH and uranium. The first sample collected each month from each location was also analyzed for chloride, fluoride, and nitrate. Locations W7, W10, and W11 were occasionally dry and could not be sampled; if W7 was dry, W8 was sampled. Two-month composites of weekly samples at W5 were analyzed for isotopic radium, as were monthly composites at W7 or W8 if W7 was dry. (Location W7 was sampled eight times, W8 four times.)

### Radiological Results

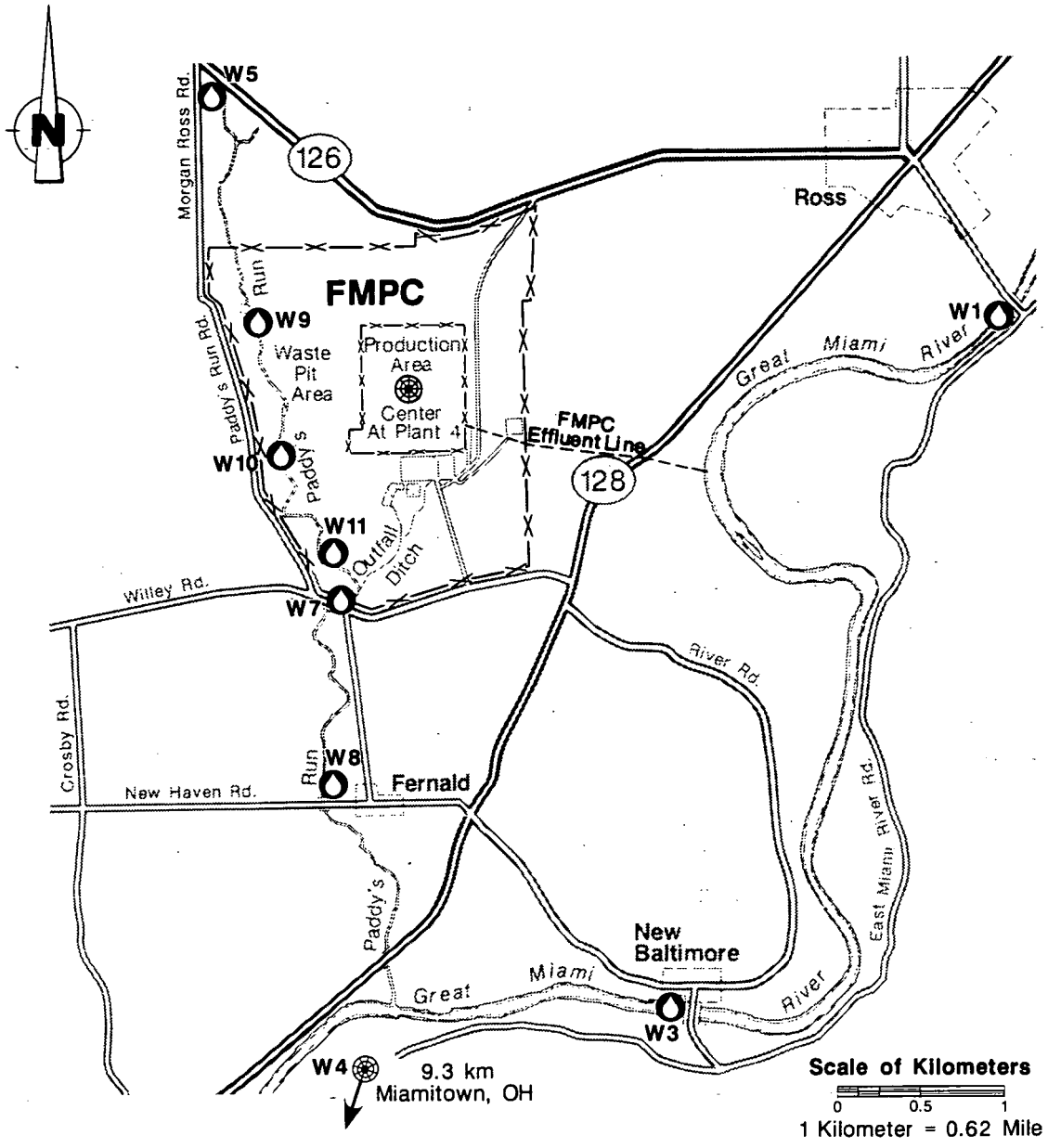
The radionuclide concentrations found in surface water samples collected during 1989 are summarized in Table 9. These data indicate that the average uranium concentration in the Great Miami River was slightly higher at sampling locations W3 and W4 downstream of the FMPC outfall than at the W1 upstream location. To more closely estimate the amount of increase in the downstream Great Miami River uranium concentration, a statistical evaluation of the individual weekly uranium results for the three river sampling

locations was performed. An increase of 0.18 pCi/l was estimated from this evaluation.[19] This is equivalent to a 13% increase in the 1.4 pCi/l background uranium concentration found at the W1 upstream location. The increase in the river uranium concentration was also calculated using the 1989 values for the total amount of uranium discharged at Outfall 001 (0.52 Curies, Table 7) and the estimated total annual river water flow ($4.11 \times 10^{12}$ liters). The calculated increase was 0.13 pCi/l which agrees well with the increase estimated from the statistical evaluation of the uranium results of weekly river samples.

There was no difference in the concentration of radium-226, radium-228, cesium-137, strontium-90, and technetium-99 found in upstream and downstream Great Miami River samples collected during 1989. As shown in Table 7, the concentrations of these radionuclides in the liquid effluent discharged to the river were very low and would result in very little, if any, increase in the background concentrations already present in the river.

Surface water samples were collected from Paddy's Run at upstream sampling point W5 and analyzed to determine background concentrations of radionuclides and other contaminants normally present in this stream. The average uranium concentration at W5 was 0.86 pCi/l. Higher average uranium concentrations were found at all downstream sampling points (Figure 28). However, average uranium concentrations at all Paddy's Run monitoring locations were well within DOE guidelines for runoff, ranging from 0.16% at W5 to 13% at W10 of the recommended maximum concentrations.

1989 results show a notable increase at location W10, which may be attributable to the additional work being done in the waste pit area. As soil is disturbed during the construction of environmental improvement projects, stormwater runoff flowing into Paddy's Run upstream of W10 may be carrying more solids, including uranium, than in past years.




## LEGEND

| | |
|---|---|
| Sampling Location | Plant Perimeter |
| Distance from Center of Production Area to Sampling Locations off Map | Production Area Perimeter |

Figure 27. Surface Water Sampling Locations

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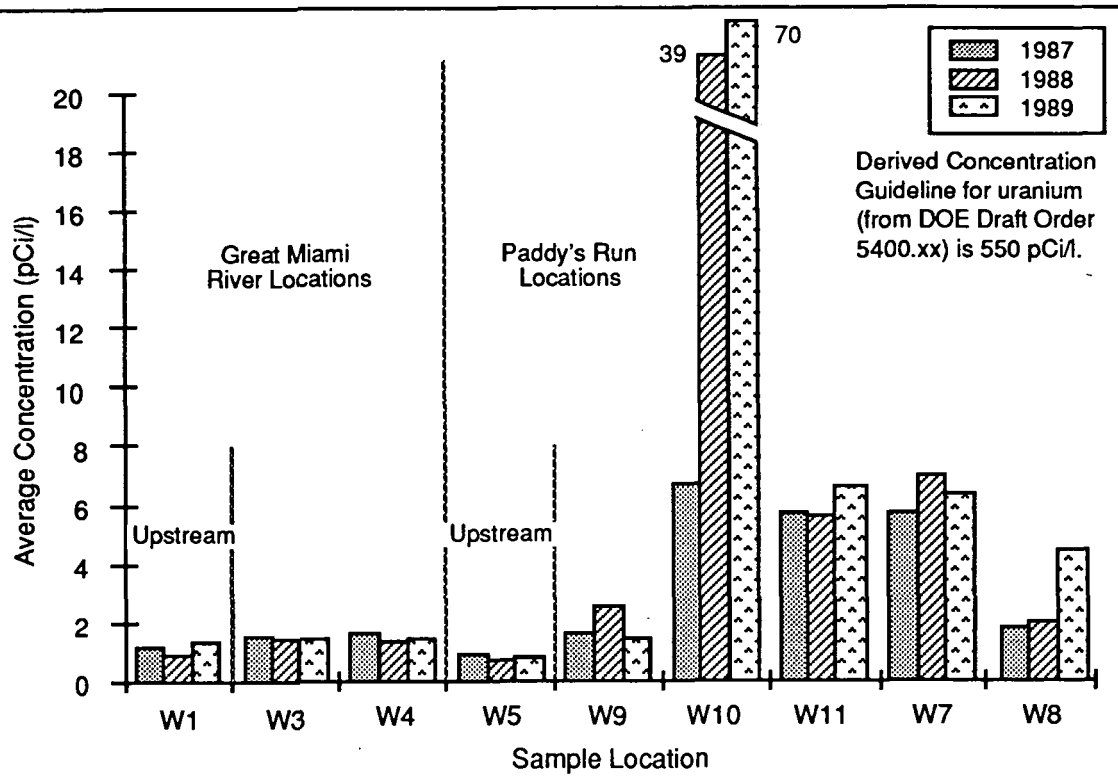


Figure 28. Average Uranium Concentration in Surface Water, 1987 to 1989

**Nonradiological Results**

During 1989, the FMPC analyzed surface water samples from the river and Paddy's Run for:

- Fluoride
- Nitrate-nitrogen
- Chloride
- pH.

The 1989 data, presented in Tables 10 and 11 and Figures 29 and 30 found in Appendix B, indicate that operations at the FMPC did not affect anion concentrations or pH in the Great Miami River or Paddy's Run. The average concentrations of these anions and pH were all below or within OEPA standards for water designated for public use. Average concentrations for these anions were the same or lower south of the site than they were at the upstream location W5 except for the fluoride concentration at location W7, which was slightly higher than W5. Note that average nitrate-nitrogen concentrations increased about 60% over 1988 at all sampling

locations in the Great Miami River, including upstream of the FMPC effluent discharge line. The increase in nitrate-nitrogen concentration was not caused by FMPC operations.

## *Sampling Sediment*

Contaminants that could be present in surface water often settle, or precipitate, and can accumulate in sediment. Thus, sampling and analysis of sediments provide a way to evaluate possible cumulative effects of routine discharges of treated effluents into the Great Miami River and the effects of uncontrolled stormwater runoff into Paddy's Run.

Sediment samples were collected at eight locations along the Great Miami River from both above and below the FMPC outfall (Figure 31). Seventy-four samples were taken at 25 locations (one location was all rock) along Paddy's Run upstream of the confluence with the outfall ditch; 53 samples were taken at 18 locations along Paddy's Run downstream of the confluence; and 24 samples were taken from eight locations along the outfall ditch. Three separate samples were collected at each location in Paddy's Run and the outfall ditch — one from each bank and one from the center of the stream bed. This sampling procedure is used because slight variations in radionuclide concentrations may be found due to sediment flushing during heavy storms, differential settling of sediments in bends or pools, or groundwater infiltration.

All sediment samples were analyzed for technetium-99 and isotopes of uranium, thorium, radium, and plutonium. There are currently no DOE or USEPA guidelines or standards for uranium or other radionuclides in sediment. For purposes of comparison, naturally-occurring uranium concentrations in Ohio soil can be estimated to range from 1.5 pCi/g (0.06 Bq/g) to 4.4 pCi/g (0.16 Bq/g).[18]

The data in Table 12 show that there were no differences in the concentration of uranium and other radionuclides found in sediment samples collected from the Great Miami River upstream and downstream of the FMPC effluent discharge line. Therefore, FMPC liquid effluent discharges did not cause any discernable increase in the background levels of radionuclides in Great Miami River sediment.

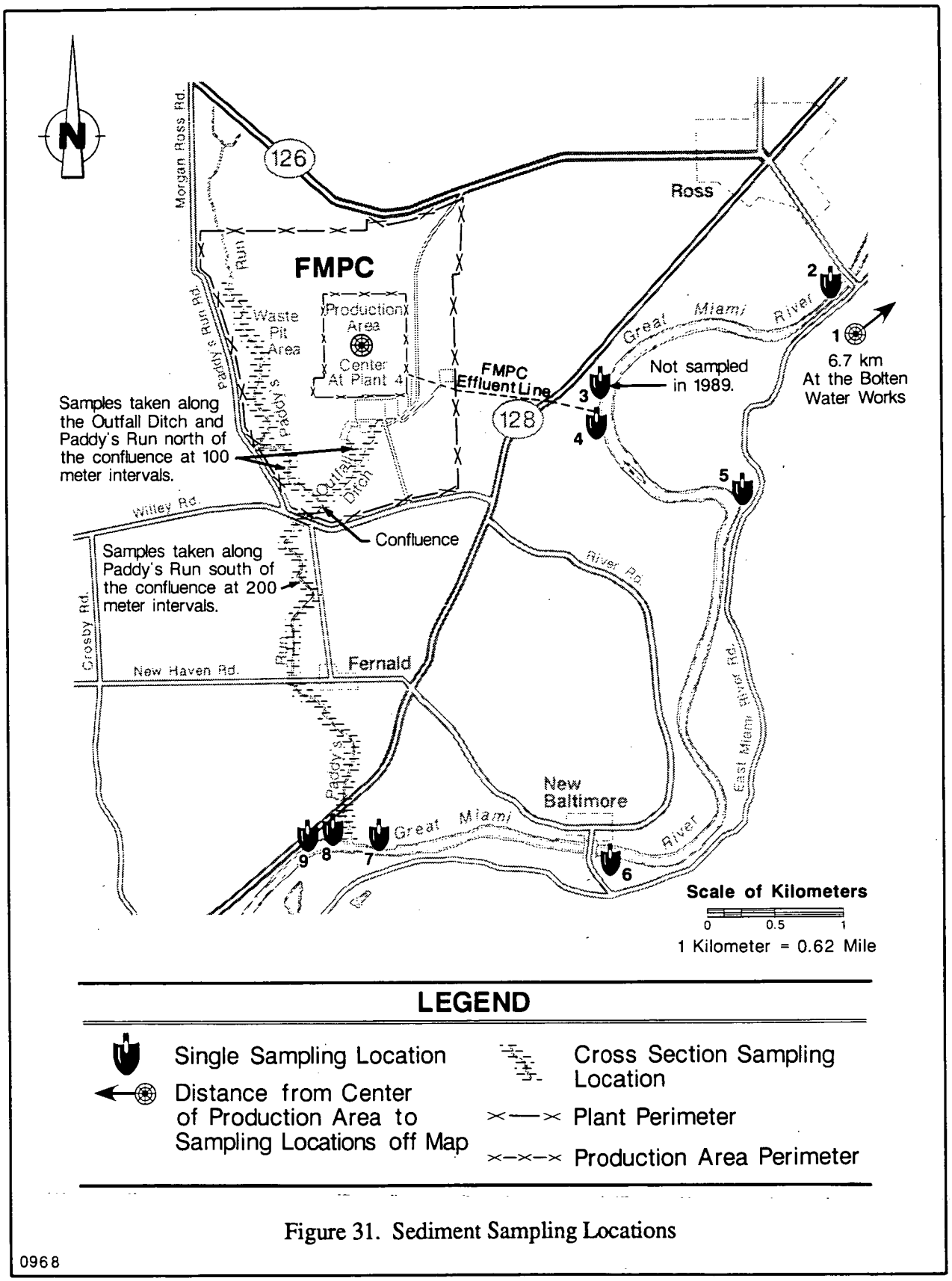


Figure 31. Sediment Sampling Locations

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Background levels of radium-224, radium-226, radium-228, thorium-232, and technetium-99 were found in outfall ditch and Paddy's Run sediment samples collected during 1989. The concentration of uranium, plutonium-238, plutonium-239/240, thorium-228, and thorium-230 were above background levels. The elevated concentration of these radionuclides is most probably the result of uncontrolled stormwater runoff from onsite flowing into the outfall ditch and Paddy's Run over the years.

## *Fish Sampling Results*

Another segment of the liquid pathway that the FMPC monitors is fish. In September 1989, the FMPC collected more than 300 fish from three locations on the Great Miami River with the help of a fisheries research team from the University of Cincinnati (Figure 32). A variety of fish species and sizes were collected, including large mouth bass, longear sunfish, river carpsucker, drum, long nose gar, gizzard shad, and channel catfish. Some of the species of fish collected feed primarily on plants and animals that live on the bottom of the river where their diets could be affected by concentrations of chemicals and uranium in sediment. Other fish species feed on small plants and algae in the middle or higher levels of the river, while other fish are predators and feed on fish and animals in the river. By collecting fish with different feeding habits, the FMPC can see if uranium concentrations differ among species.

The University of Cincinnati team studied the fish populations in the Great Miami River and determined a number of things. First, the diversity and abundance of fish populations in the Great Miami River have not changed appreciably since 1984. Second, though the habitats at the three sampling locations differ, the habitats themselves have not changed since 1985 except for location 3 which is affected by nearby gravel quarrying and the removal of part of the dam. Third, the university scientists report that populations of fish throughout the river remained healthy in 1989.[20]

The average uranium concentration reported in fish from all three sampling locations was consistent with results reported before 1988. 1988 data were surprisingly and questionably higher than normal as explained in the 1988 EMR. The fish data for 1988 and 1989 are presented in Table 13. An estimated dose from eating fish caught in

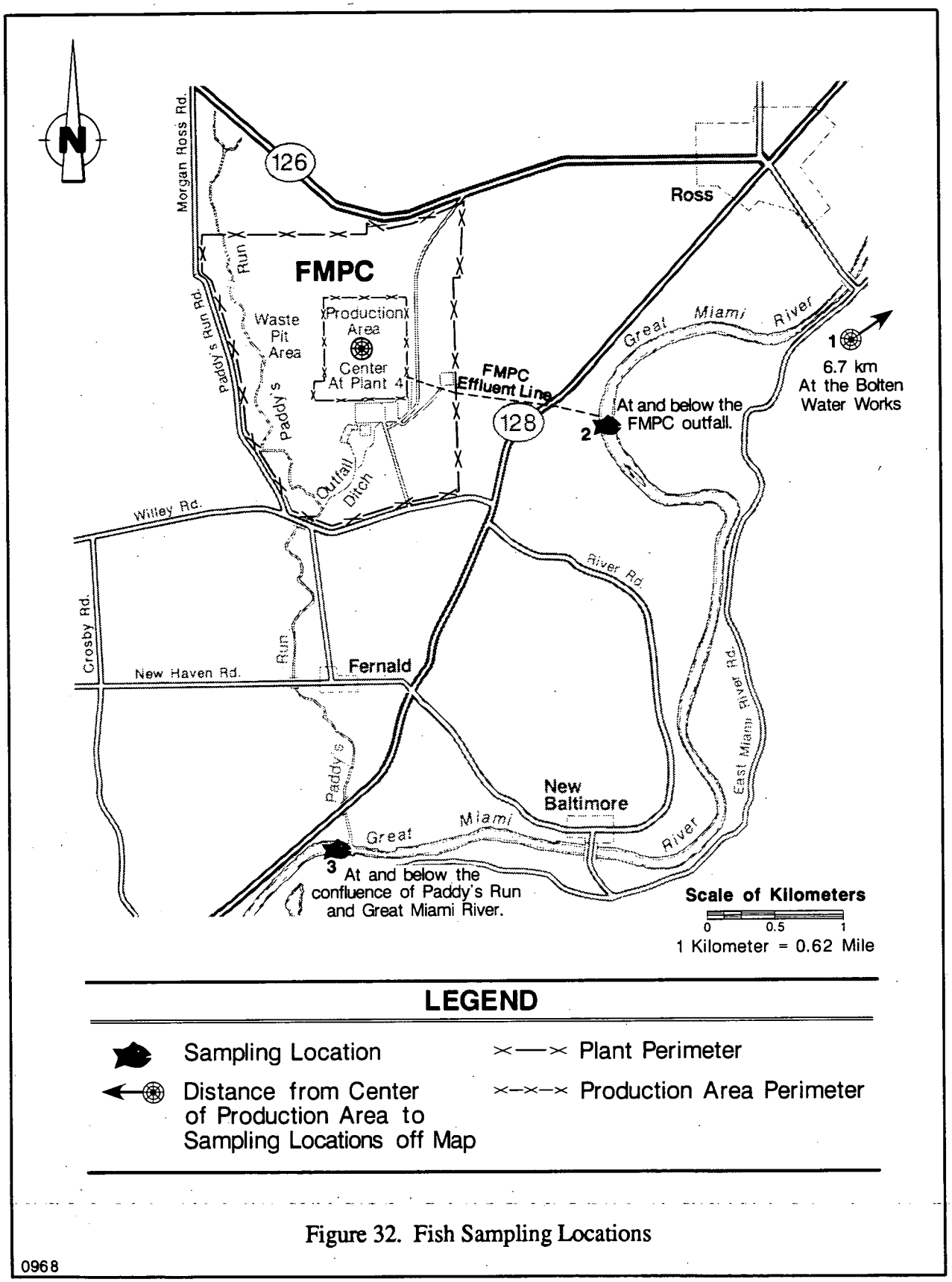


Figure 32. Fish Sampling Locations

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the Great Miami River at the FMPC outfall is discussed in the next chapter.

## Monitoring the Groundwater Pathway

Groundwater is a vital component of the liquid pathway. Consequently, the FMPC carefully monitors the groundwater in and around the site to identify and track the movement of contaminants which may be present in the aquifer. By drilling wells, scientists can analyze the groundwater for contaminants as well as learn much about the soil and its ability to restrict the movement of contaminants into the groundwater. This enables the FMPC to better define the steps the site should take to control present contamination and to prevent additional contamination from occurring.

The FMPC has installed some cluster wells to map and characterize groundwater. A cluster well is a group of two or more wells of different depths drilled at the same location which are used to sample different water-bearing zones within the groundwater. Figure 33 shows the depths of the intake screens the water is drawn through. Environmental Monitoring wells 3001 and 4001 are cluster wells, as are 3008 and 4008 (Figure 34).

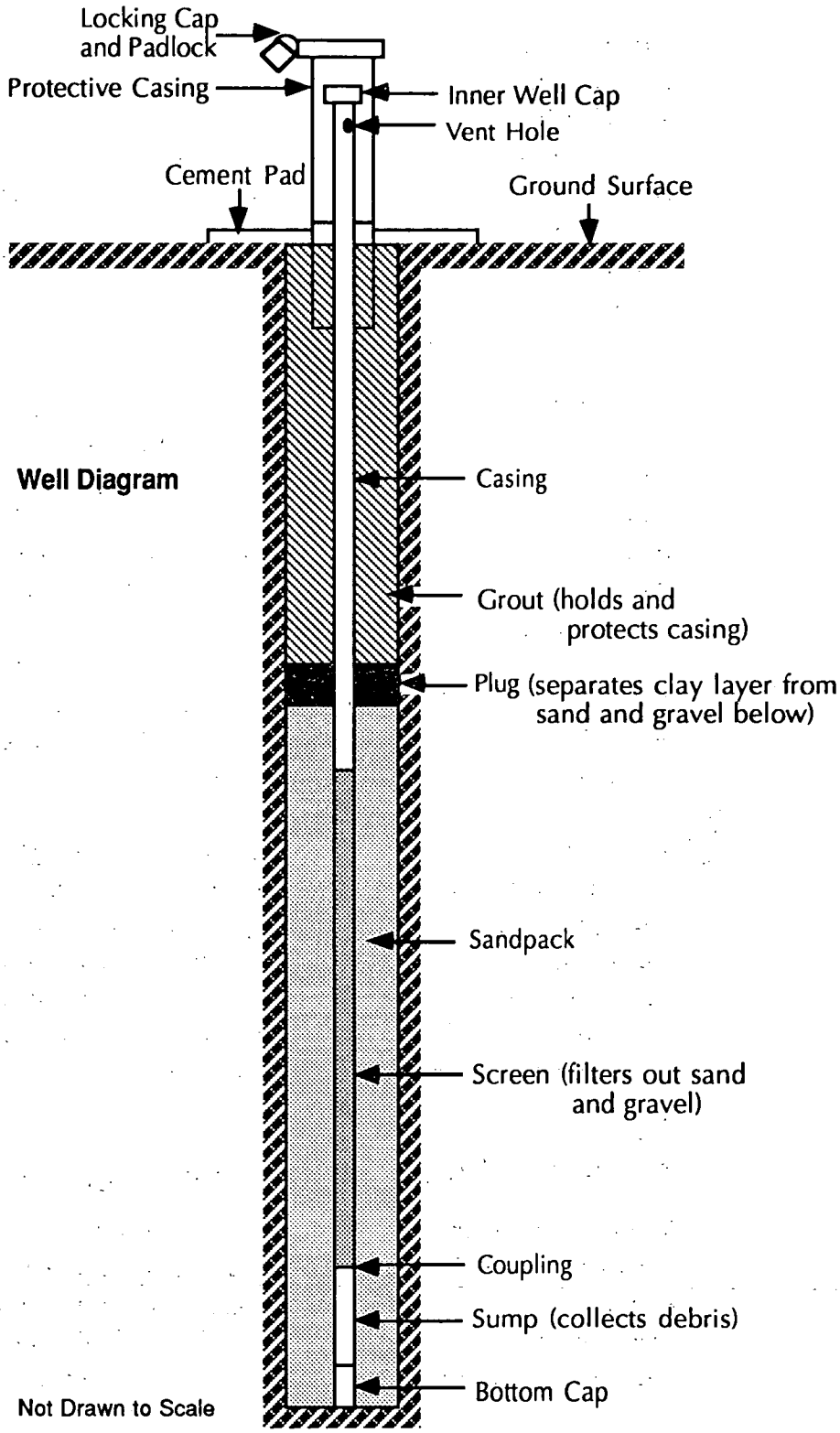
The depth of the well and the water-bearing zone it extends into is denoted by the first digit of the well number. Wells extending into the groundwater within the till are denoted as 1000-series.

Wells extending into the upper portion of the sand and gravel aquifer are denoted as 2000-series wells. The 3000-series wells are placed within the lower portion of the upper sand and gravel aquifer. The 4000-series wells are installed in the sand and gravel aquifer which underlies another layer of clay, called "blue clay." Wells 4101, 4102, and 4103 are the FMPC production wells which supply potable water for the site, and they draw water from under the blue clay layer of the aquifer.

## History of Groundwater Monitoring at the FMPC

The groundwater monitoring program has been evolving throughout the history of the site. The three production wells which supply drinking water to the plant were among the first drilled during the construction of the site in 1951. From 1959 to 1965, eleven monitoring wells were installed in the waste pit area to see if pit

This diagram depicts the construction of a typical well used for sampling groundwater. These wells are located both on and off the FMPC site. They range from 35 to 250 feet deep.




**Well Diagram**

Not Drawn to Scale

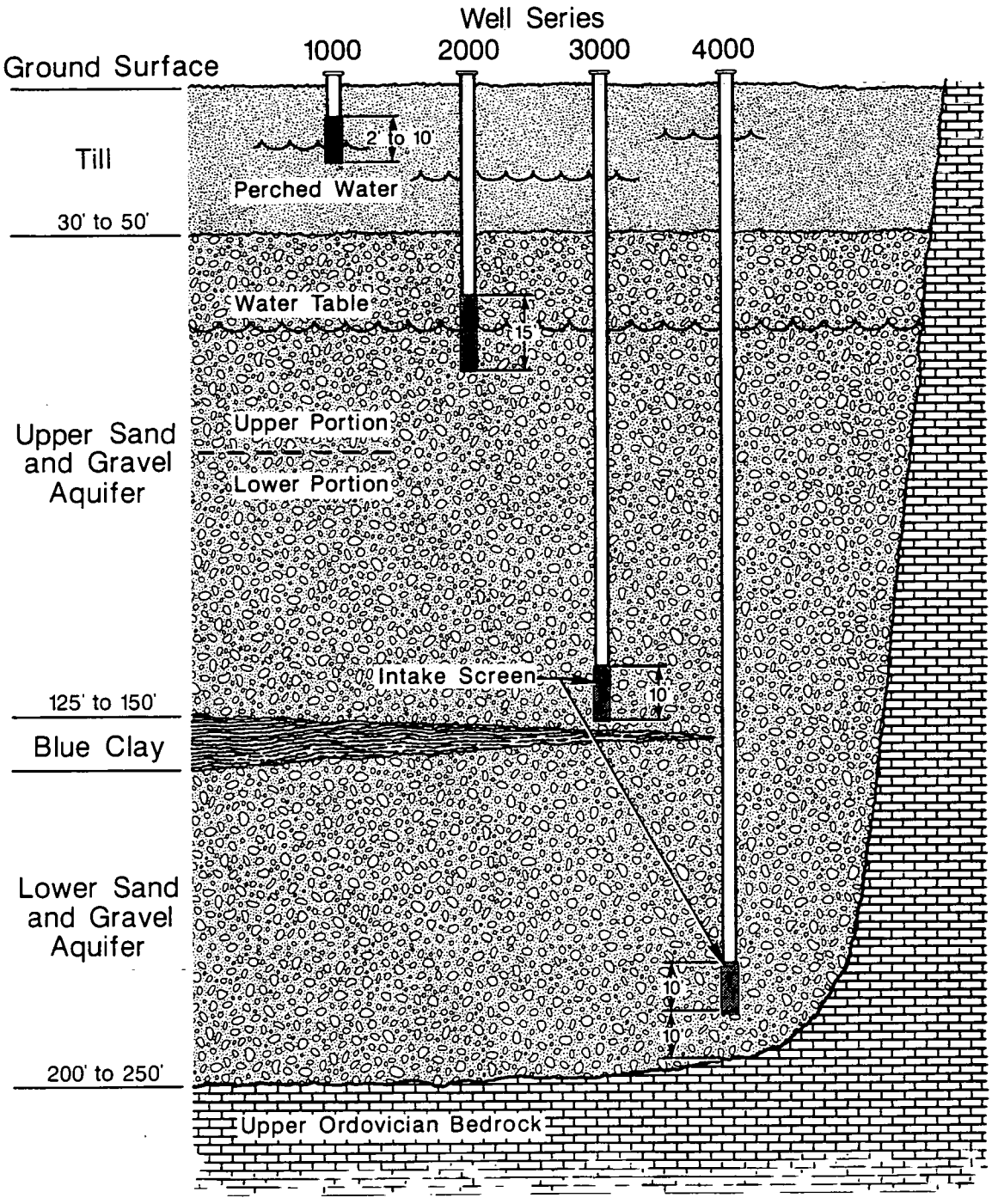



Figure 33. Monitoring Well Depths and Screen Locations

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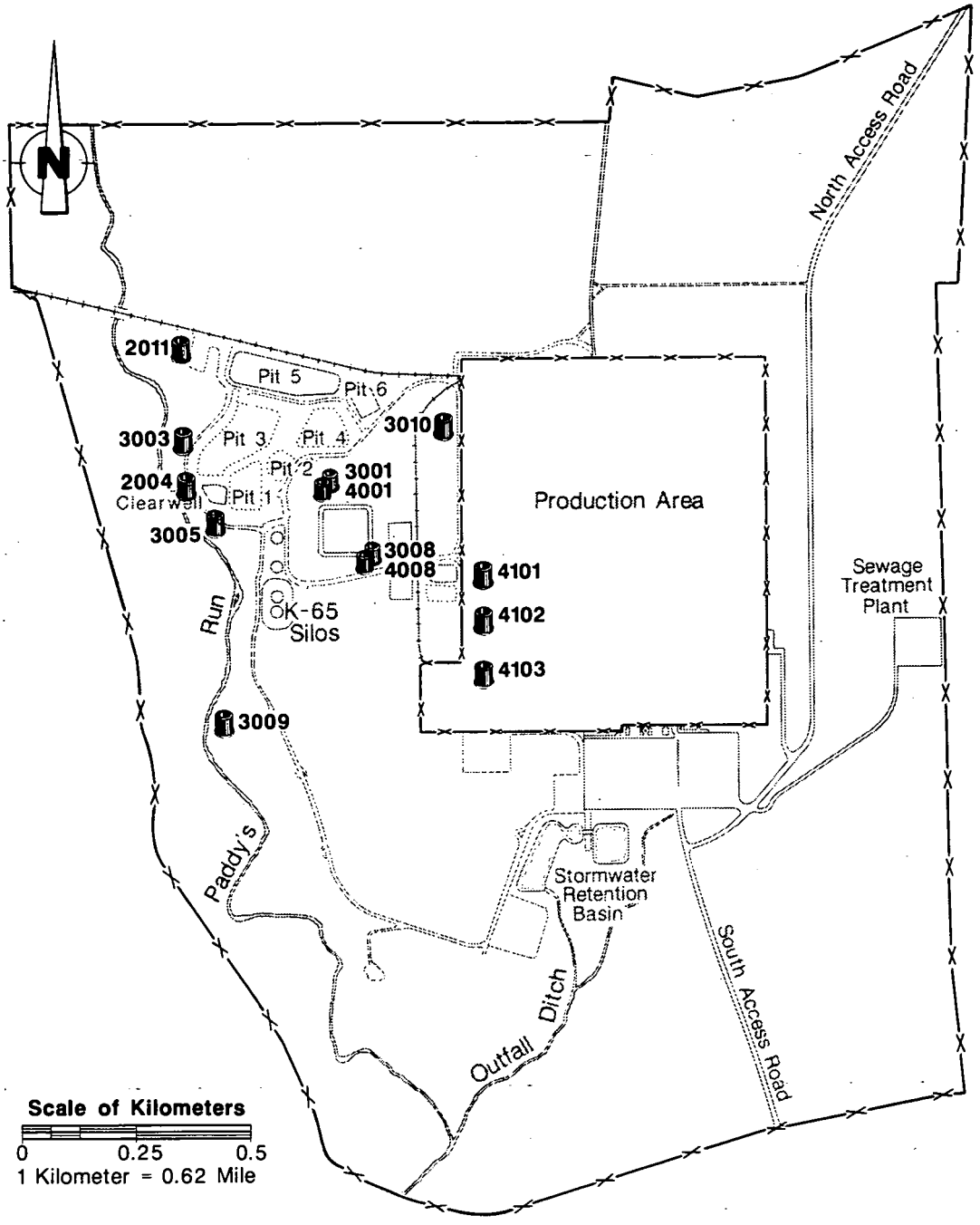
operations were affecting the groundwater. Since then, three of the ten monitoring wells have been deepened and three others capped as more waste pits were built. Two wells were added in 1982. These remaining 13 wells, including the three production wells, continue to be sampled on a regular basis for radioactive and nonradioactive parameters as part of the ongoing Environmental Monitoring Program. Their locations are shown in Figure 34.

In late 1981, the State of Ohio found elevated alpha and beta activities in one well in the Fernald area. The FMPC sampled several wells and found that the beta activity was due to potassium-40, an emitter not present in FMPC materials, and the alpha activity was due to uranium. The FMPC reported this information to the State in November 1981.

This finding prompted an expansion of groundwater monitoring at the FMPC. The FMPC began sampling existing private wells near the site in February 1982. Thirty private wells were sampled during 1989, and the results are discussed later in this chapter. In the early 1980s, 23 wells were drilled primarily in the waste pit area and in other nonproduction areas to identify the extent of the contamination. Some of these were sampled during 1989 as part of the Resource Conservation and Recovery Act (RCRA) Groundwater Assessment Program.

During the 1980s, about 400 wells were installed for the several groundwater studies conducted at the site. At the time of this report, nearly all the monitoring wells were included in one of the three primary groundwater programs at the FMPC: Resource Conservation and Recovery Act (RCRA), Remedial Investigation/Feasibility Study (RI/FS), and the Environmental Monitoring Program. An important task facing the FMPC is integrating these three programs into a comprehensive long-term program. The focus of each program is discussed in the following paragraphs.

**The RCRA Groundwater Assessment Program** began as a result of the disposal of the hazardous waste barium chloride in waste pit 4 from 1980 to 1983. The FMPC was required, under RCRA, to identify whether hazardous waste had entered the groundwater, and, if so, the rate, extent of migration, and concentration of any hazardous waste in the groundwater. This was accomplished by conducting two major monitoring programs. The




**LEGEND**

Single Well

Cluster Well

Plant Perimeter

Production Area Perimeter

Figure 34. Onsite Groundwater Monitoring Wells

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first was the RCRA Detection Program. When the results indicated significant changes of indicator parameters, the FMPC then conducted the second program, the RCRA Groundwater Quality Assessment. This program is discussed in Chapter Six, "Waste Management Activities."

**Groundwater monitoring under the Remedial Investigation and Feasibility Study** began in July 1986. This study is investigating the nature and extent of potential environmental impacts from past and current operations at the FMPC. One investigative tool is groundwater monitoring. For example, during 1989, the RI/FS Facility Testing program installed more than 150 two-inch diameter wells (piezometers) in the production area to look for contaminants in groundwater within the till. A second example are the eight wells that were installed in the vicinity of the K-65 Silos. At least two more wells will be installed in this area during 1990 to continue monitoring the migration of pollutants. The RI/FS program is discussed in Chapter Seven, "Special Studies and Significant Events."

**The Environmental Monitoring groundwater monitoring program** regularly samples onsite monitoring and production wells. Until the RCRA and RI/FS programs began, this program provided the majority of the groundwater data for the FMPC. This program continues to provide valuable data for groundwater evaluations. The results from this program are presented later in this chapter.

## *Consolidating Existing Groundwater Programs*

In anticipation of completing the RI/FS, the FMPC began designing a comprehensive, long-range groundwater monitoring program while continuing the sampling schedule for the RCRA Assessment program, the RI/FS program, and the ongoing Environmental Monitoring Program. In 1989 the RCRA Assessment program was modified and now includes forty-three wells in the vicinity of the waste pits which were installed under the RI/FS program. The scope of this consolidated groundwater monitoring program includes the program goals and objectives of the three programs:

- To detect and determine the extent and rate of migration of any onsite or offsite groundwater contamination

- To monitor uranium concentrations and water quality parameters in community or public water supplies near the FMPC
- To establish and track natural concentrations of radionuclides and hazardous substances found in groundwater not influenced by FMPC operations in order to assess site-specific contributions to the groundwater
- To provide information for the ongoing remedial activities.

The wells are sampled for radionuclides, general water quality indicators, metals, and toxic organics. The program is revised as required by new findings.

## *Results from the Environmental Monitoring Groundwater Program*

In 1989, the Environmental Monitoring groundwater sampling program consisted of the 13 onsite monitoring and production wells and 30 private wells located offsite. The wells in each group are sampled according to specific schedules (monthly, quarterly, and annually), and the samples are analyzed for specific parameters (radioactive and nonradioactive). Results of all groundwater sampling were compared to National Primary and Secondary Drinking Water Regulations as well as DOE guidelines.

A study by the U.S. Geological Survey states that natural levels for total uranium in groundwater in most areas in the United States range from 0.068 to 6.8 pCi/l (0.0025 to 0.25 Bq/l).[21] Environmental Monitoring personnel examined data for the last three years from private wells north of the site.

These data indicate that background concentrations of uranium in groundwater in the area of the FMPC range from about 0.068 pCi/l to about 2.0 pCi/l.[22]

**Conversion Factors for Natural Uranium in Water**

| mg/l | Parts per Million | pCi/l |
|---|---|---|
| 1 | 1 | 680 |
| **µg/l** | **Parts per Billion** | **pCi/l** |
| 1 | 1 | 0.68 |
| 2 | 2 | 1.4 |
| 3 | 3 | 2.0 |

## Onsite Wells, Radiological Parameters

The onsite production wells (4101, 4102, 4103) were sampled four times for uranium and three times for alpha and beta activity. The onsite monitoring wells were sampled three times for uranium and twice for alpha and beta activity (Tables 14, 15, 16). All concentrations of uranium in the onsite wells were compared against a reference concentration of 22 pCi/l, a value calculated from the USEPA proposed drinking water standard of 4 mrem/year effective dose. All uranium concentrations in onsite wells in 1989 were below this reference value.

> USEPA has also proposed 30 pCi/l as a reference value for uranium concentration in groundwater as part of the Uranium Mill Tailing Remedial Action program. (CFR 52.185, 9/24/87)

Figure 35, reproduced on the following page, displays average uranium concentrations from 1987 to 1989 for the onsite wells. Uranium concentrations decreased significantly in wells 3003, 3009, and 3010.

Gross alpha and beta activity are used as indicators to identify areas where further analysis of specific isotopes is warranted. A gross alpha measurement is a different type of measurement than a uranium measurement, which is a quantitative measurement. The gross alpha measurement, on the other hand, is a more qualitative measurement. Gross alpha is principally used as a screening test or an indicator parameter that would trigger more specific tests. It is reported, as is the gross beta measurement, because there are USEPA drinking water guidelines to compare against for these parameters.

The maximum gross alpha activity of 20 pCi/l, found in well 2004, was above the standard of 15 pCi/l, but all other values were well below the standard (Table 15). The maximum gross beta activity was found in well 3010 and was 46% of the standard of 50 pCi/l (Table 16). Overall, the differences in the two parameters between 1988 and 1989 showed no trends outside of what would be considered due to natural variability, except for well 2004, which increased from 1987 (this well was not sampled in 1988 due to refurbishing). Uranium concentrations also increased which probably accounts for the increase in alpha and beta activities in this well.

Figures 36 and 37, found in Appendix B, show the average gross alpha activity and gross beta activity, respectively, in onsite wells from 1987 through 1989.

**Onsite Wells, Nonradioactive Parameters**

During 1989, two samples from all onsite monitoring wells (three samples from the production wells) were analyzed for nitrate-nitrogen concentrations. Results were less than the USEPA drinking water standard of 10 mg/l (Table 17). Well 3010, which had exceeded the standard in 1986 and 1987, (the well was not sampled during 1988 due to refurbishing) decreased significantly in 1989 and averaged less than 0.25 mg/l (Figure 38 in Appendix B).

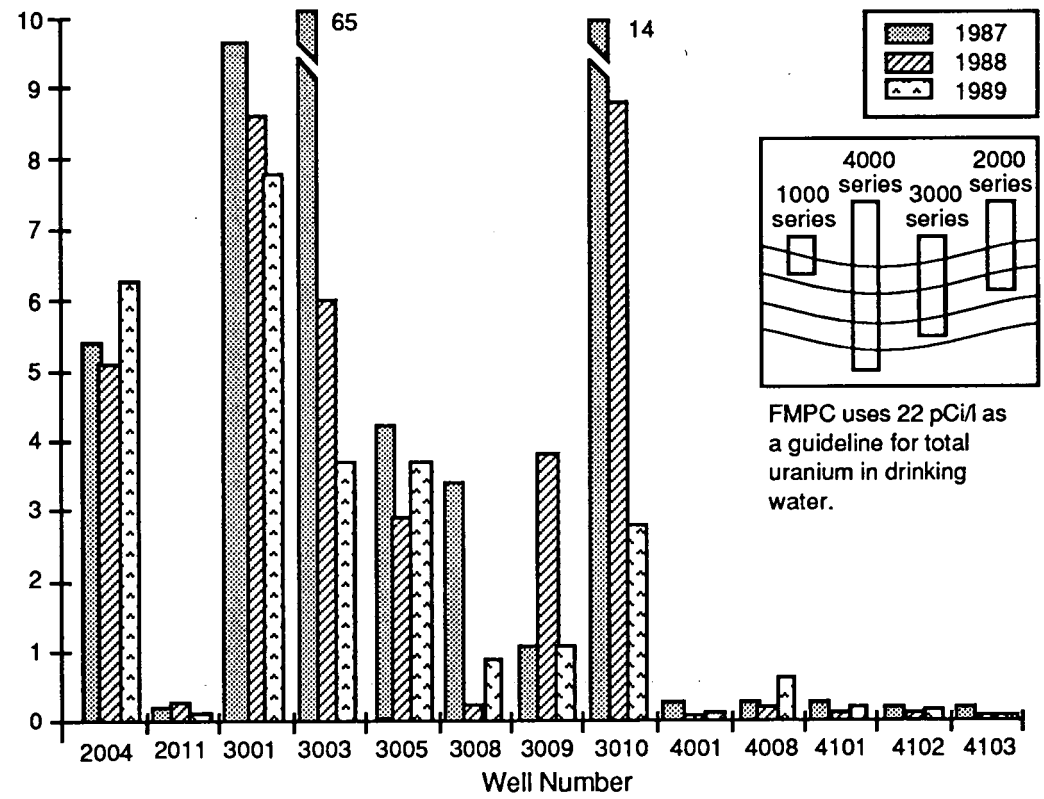
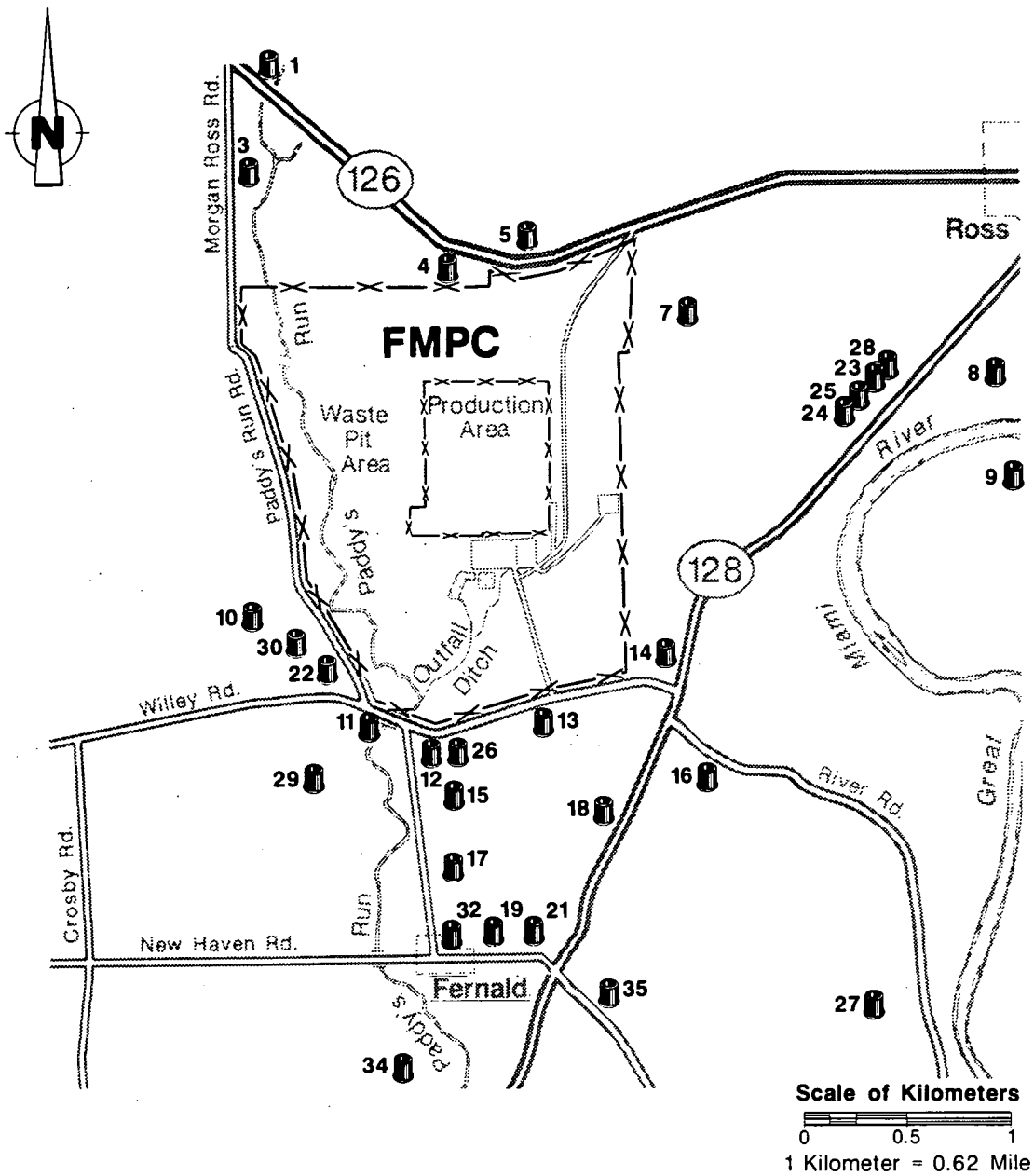



Figure 35. Average Uranium Concentration in Onsite Wells, 1987 to 1989

The onsite samples were also analyzed for sulfate, chloride, and pH (Tables 18, 19, and 20). All onsite wells were within the USEPA. standard of 250 mg/l for sulfate and chloride except for sulfate concentration in well 3010, which was significantly above the standard. Sulfate concentrations in the onsite wells ranged from <10 mg/l to a maximum of 664 mg/l in well 3010. Chloride concentrations ranged from 11 mg/l in well 4008 to 67 mg/l in well

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Sampling Location

Plant Perimeter

Production Area Perimeter

Figure 39. Offsite Groundwater Monitoring Wells

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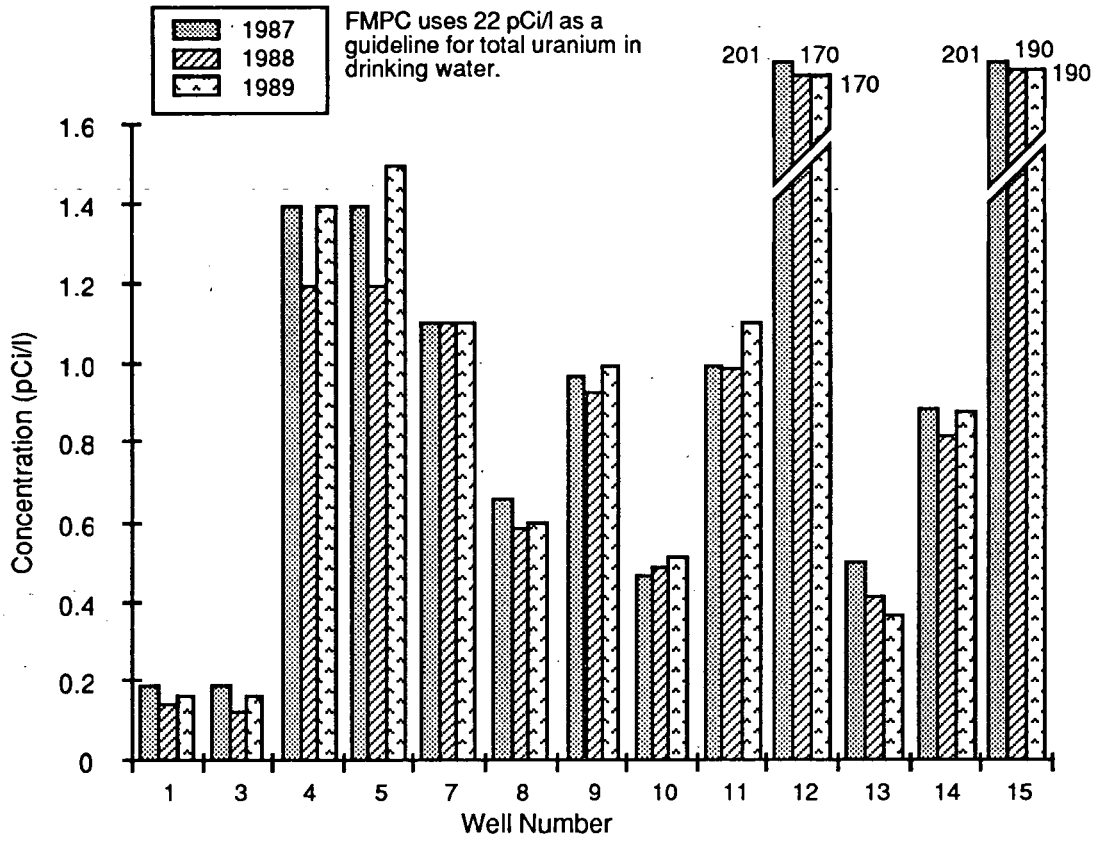



Figure 40. Average Uranium Concentration in Offsite Wells, 1987 to 1989

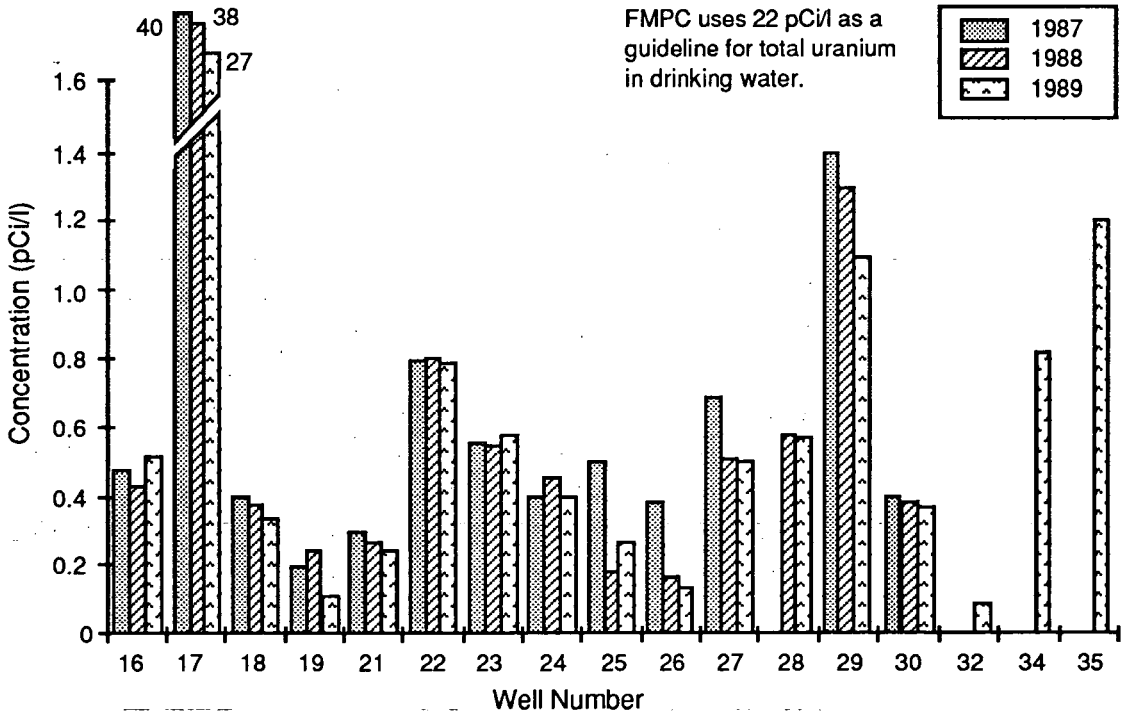



Figure 41. Average Uranium Concentration in Offsite Wells, 1987 to 1989

3010. The pH values were all within the accepted range of 6.5-8.5 for drinking water standards.

### Offsite Wells, Radioactive Parameters

During 1989, offsite wells belonging to individuals and companies in the vicinity of the FMPC were sampled monthly and analyzed for total uranium (Figure 39). Environmental Monitoring Groundwater Program offsite wells do not carry the four-digit numbering system, but are numbered according to when they were first sampled for this program. Wells 32, 34, and 35 were added to the program during 1989. Data from the offsite sampling program are presented in Table 21. Figures 40 and 41 show average uranium concentrations found in offsite wells during 1987-1989.

As in past years, the average uranium concentration in samples collected during 1989 from the offsite wells, except for wells 12, 15, and 17, were well below the guideline of 22 pCi/l (0.81 Bq/l) and were within the natural background range for uranium concentration in groundwater.

### Offsite Wells, Nonradioactive Parameters

The July 1989 samples from the offsite wells were analyzed for sixteen metals in addition to uranium (Table 22 and Figure 39).

- Silver
- Arsenic
- Barium
- Calcium
- Cadmium
- Chromium
- Copper
- Iron
- Potassium
- Magnesium
- Manganese
- Sodium
- Nickel
- Lead
- Selenium
- Zinc

Of these 16 metals, no DOE or USEPA standards have been established for calcium, potassium, magnesium, sodium, and nickel. Though concentrations of iron and manganese were generally higher than USEPA drinking water guidelines, their concentrations are typical for groundwater in this area.[23, 24, 25] The concentration of arsenic and selenium in well 19, and selenium in 12 other wells, were above the drinking water guidelines. The FMPC is not considered a source of these metals.

## SUMMARY OF LIQUID PATHWAY RESULTS FOR 1989

The FMPC extensively monitors its liquid effluent and area surface water and groundwater to detect and track the movement of contaminants that can originate from the site.

The quantities of individual radionuclides discharged to the Great Miami River were within DOE guidelines. However, the sum of the percent of guideline of each radionuclide discharged was greater than 100%, thus exceeding the discharge guidelines. The FMPC is designing an advanced wastewater treatment facility which will reduce the amount of both radioactive and nonradioactive discharges to the river.

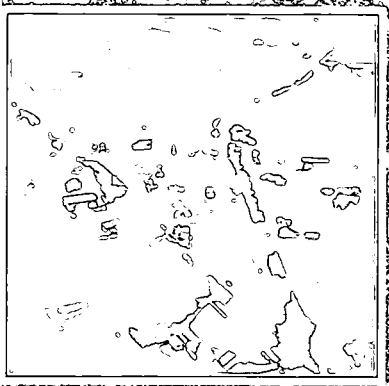
The FMPC complied with the NPDES requirements for nonradioactive contaminants more than 98% of the time during 1989.

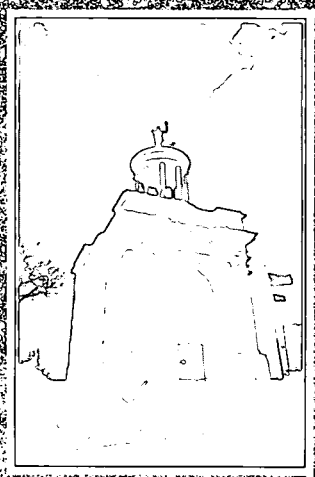
Surface water sampling results indicate that uranium concentrations in Paddy's Run increased near the K-65 Silos. A project is planned to reduce uncontrolled stormwater runoff to Paddy's Run from the waste pit area which will decrease the amount of uranium entering this stream.

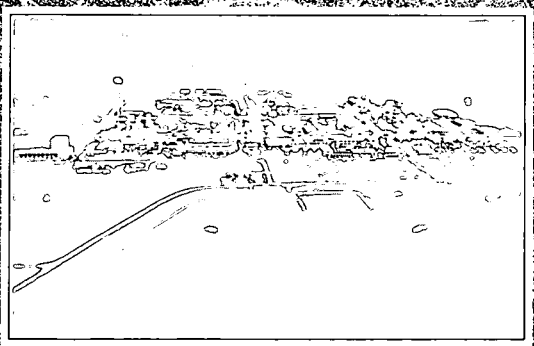
The groundwater monitoring program continued to sample private wells. The uranium concentration in these wells was within the background range except for the three wells identified previously as being contaminated.

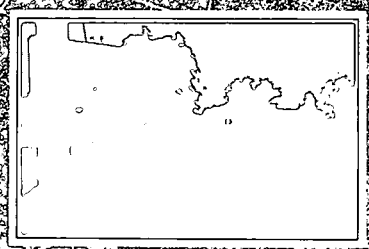
# CHAPTER 4

## Estimated Radiation Doses for 1989









CHAPTER FOUR

# Estimated Radiation Doses for 1989

One of the chief public concerns about any facility that handles radioactive materials is that people in the area will be exposed to harmful amounts of radiation. This chapter provides estimates of the radiation doses resulting from FMPC operations during 1989.

Estimates of dose from the air pathway, which is the critical pathway for the FMPC, were calculated according to 1989 NESHAP requirements which exclude radon emissions. The estimates indicate that people in the area surrounding the FMPC were exposed to a committed effective dose of less than 6% of the DOE guideline defining radiation protection of the public and the environment (Table 23).[4] This dose was calculated for continuous exposure to FMPC airborne radionuclide emissions. The total of the measured and estimated quantities of each radionuclide was used to calculate the dose.

In addition, the FMPC measured radon concentrations along the site boundary. The average measured above-background concentrations of radon were 8% of the DOE guideline.

This chapter explains how the FMPC estimates the maximum doses an individual and the public could receive through the air pathway from FMPC operations. Similarly, dose calculations are made for the liquid pathway and external radiation based on monitoring data collected throughout the year.

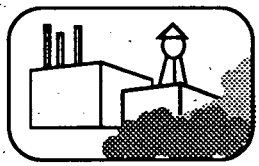
## Air Pathway Dose Calculations

Due to historical air emissions at the FMPC with the resulting onsite surface contamination having the potential for resuspension, the air pathway is considered to have the greatest potential for offsite exposure of the public. Consequently, the air pathway is considered the critical pathway. The liquid pathway, while also important, is considered to have a lesser potential for exposure of the public, primarily because of the absence of large-scale public water supplies near the FMPC.

The doses a person could receive through the air pathway from FMPC operations in 1989 were calculated using the AIRDOS-EPA computer model. This model was developed by Oak Ridge National Laboratories (ORNL) under USEPA sponsorship to determine if sites which discharge airborne radionuclides comply with NESHAP requirements of the Clean Air Act (CAA).

AIRDOS-EPA calculates concentrations of released radionuclides in air, on the ground, and in food grown locally. It then calculates intakes of and human exposures to the radionuclides in the various environmental media. Dose conversion factors are then applied to the calculated exposures and intakes of radionuclides to estimate individual and collective dose equivalents.[26] The calculations follow standards established by the International Commission on Radiological Protection (ICRP) Reports 26 and 30, with some modifications recommended by the USEPA.[5]

For the 1989 dose calculations, the FMPC included data such as the annual emissions of radionuclides (listed in Table 24), population distribution data (listed in Table 25), and site-specific meteorological data. The next section describes how the FMPC estimates airborne emissions from the site.



## *Methods Used to Determine Air Emissions*

United States Environmental Protection Agency regulations stipulate that the AIRDOS/DARTAB model be used to estimate how much radiation exposure (dose) nearby residents and the population in general might possibly be exposed to as the result of radioactive airborne emissions from facilities such as the FMPC.[6] Many types of data are required for making AIRDOS-EPA dose estimates: the number and height of discharge stacks, meteorological information such as the amount of precipitation and wind speed in various directions, and of course, the amounts of radioactive nuclides discharged from each emission source. Much of the data required for the dose estimates such as stack heights and amount of rainfall can be obtained by direct measurement. However, the amount of airborne radioactive material released from certain emission sources, such as large surface area waste pits, cannot be determined readily by actual measurements.

In these cases, the amounts of radioactive airborne material released must be estimated. Such estimates had to be made for several emission sources at the FMPC including the Laboratory Building, the cooling towers at the Water Treatment Plant, and the waste pits. The FMPC made very conservative estimates for these and all other emission sources which were not measured directly. This was done for two purposes. First to ensure that the AIRDOS-EPA dose estimates were not underestimated but rather were the maximum possible doses that could have resulted from FMPC operations during 1989. Secondly, to demonstrate that FMPC airborne radionuclide discharges complied with NESHAP clean air requirements even if very conservative estimates were made for all possible unmonitored emission sources. As discussed in the "Evaluating AIRDOS-EPA Results" section, this conservative approach resulted in the airborne emissions from the FMPC waste pits being grossly overestimated.

The method used to determine air emissions from the FMPC for 1989 basically consisted of adding either measured or estimated losses from:

- Monitored stacks
- Unmonitored stacks
- Scrubbers
- Building vents
- Fugitive emissions from the waste pits.

Measured plus estimated uranium air emissions for 1989 totaled 30.1 kg (66.4 pounds). This represents a 72% reduction from the 1988 air emissions of 107.8 kg (237.5 pounds) and can be attributed to the suspension of production. Some of the production sources which operated during 1989 were run for start-up and testing purposes only. These emissions have been included in the totals.

**Monitored Stacks**

The 33 monitored stacks, a majority of which are exhausts from dust collectors, make up the greatest number of discharge sources at the FMPC. All sources are monitored by taking continuous isokinetic particulate samples, which are routinely analyzed for uranium. Collectively these sources accounted for about 3% of the uranium emissions.

### Unmonitored Stacks

There were 15 unmonitored stacks that operated on a limited basis during 1989 and which accounted for about 11% of the uranium losses for the year. This included losses from the cooling towers (Building 20C in Figure 3). Estimates were derived by either engineering calculation, periodic stack emission measurements, or a combination of both. In general, a detailed analysis was made of the processes, the characteristics of materials emitted, and the operating time for each system. This information was used to derive emission factors which, when multiplied by amounts of material processed over a period of time, provided an estimate for emissions of unmonitored processes.

### Scrubbers

A scrubber is a pollution control device that uses a liquid to remove contaminants from air. Two scrubber systems operated during 1989, both in Plant 8: the Rotary Kiln and the Primary Calciner. Together these sources accounted for about 12% of the uranium emissions for the year. Methods for determining losses are based on an emission factor (per hour) times the actual number of hours these sources operated. The current emission factor was derived from stack emission tests conducted according to USEPA methods.

### Building Vents

Emission losses from building vents make up about 2% of the losses reported for 1989. Building ventilation emissions were calculated based on data collected by continuous air monitors located in each plant near processes thought to produce radionuclide emissions.

The yearly emission for each plant is estimated from the average annual concentration reported from the plant continuous air monitors, the estimated hours each fan operated, and a 0.1 dilution factor. Since the plants are measured only in the areas of highest suspected concentration, the actual average uranium concentration in air in the plants is significantly lower than the average calculated from continuous air monitor results.[27]

### Laboratory Emissions

These emissions contributed about 6% of the total uranium losses calculated for the year. These estimates were based upon the average number of samples processed per year in each hood, the

probable loss per sample, and the estimated uranium concentration of the sample.

**Fugitive Emissions from the Waste Pits**

Based on calculations, the greatest percentage of air emissions lost from the site during the operating year, about 65% of the total, was attributed to fugitive dust from the waste pits. The estimate is based on a USEPA method for determining losses in and around storage piles, and has been adapted for calculating losses from the waste pits. Basically, the estimated emissions are based on the area of the waste pits exposed to winds that exceed 12 miles per hour on days that receive less than 0.01 inch of rain.

In calculating fugitive dust emissions from the waste pits, personnel determined that only wind erosion generated a significant amount of fugitive dust. No materials were added or removed from the waste pit area, and vehicle movement in the pit area was minimal. All computations were performed according to a method published by the USEPA.[28]

## *Estimated Maximum Dose to an Individual in the Public*

The following maximum doses from FMPC air emissions (excluding radon) to an individual were calculated using the AIRDOS-EPA model:

- 5.2 mrem (0.052 mSv) committed effective dose
- 34 mrem (0.34 mSv) to the lung (pulmonary tissue) (Table 23).

The calculated doses are well below DOE guidelines and the NESHAP standards for 1989.

The FMPC identifies the resident who theoretically could receive the greatest dose through the air pathway (excluding radon). To accomplish this, the 1989 airborne emission data compiled by the FMPC were entered into AIRDOS-EPA along with information about the population distribution surrounding the FMPC. The area was divided into 16 wind sectors and the residence closest to the FMPC in each sector identified. Doses at each selected residence were calculated, and the highest total dose at a residence was then taken to be the dose received by the maximally-exposed individual.

An additional important conservative assumption was that an individual at each location in the 16 wind sectors remained outside at his or her home 100% of the time for the entire year.

Dose calculations were made for nearby residents in each of the 16 sectors. Even though the predominant wind direction at the FMPC is from the southwest (Figure 42), the resident who received the maximum estimated dose during 1989 lives 1,150 meters (0.7 miles) north of the center of the FMPC production area.

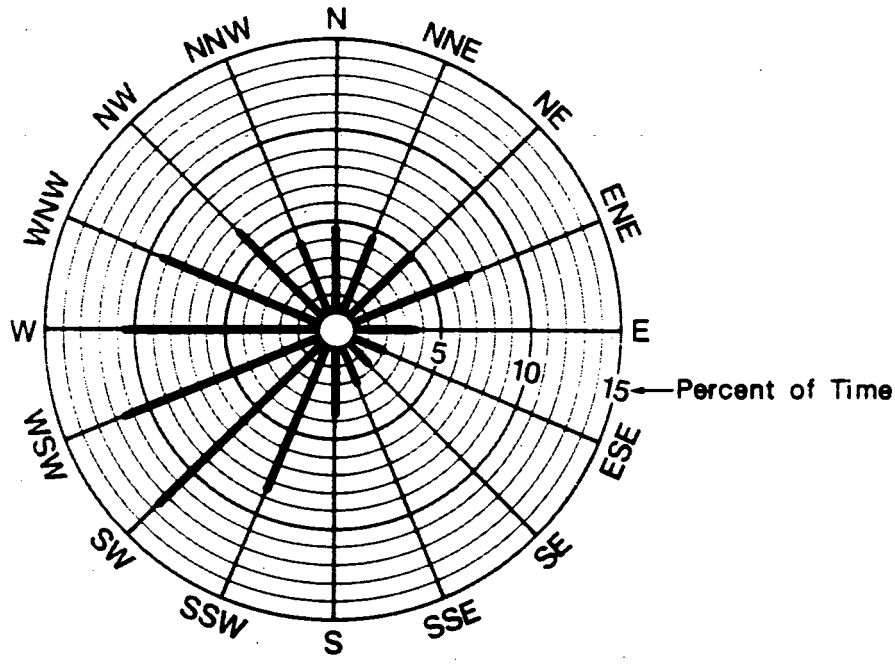
The estimated effective dose to the maximally-exposed offsite individual for 1989 (5.2 mrem) is a 79% increase over 1988, and is primarily due to an increase in the estimates for fugitive emissions from the waste pits along with changes in the site meteorological data. Nevertheless, this is less than 6% of the DOE guideline for protection of the public for all pathways, and the maximum organ dose of 34 mrem (0.34 mSv) is 45% of the USEPA NESHAP standard for annual exposure to specific organs.

## Estimated Dose to the General Public

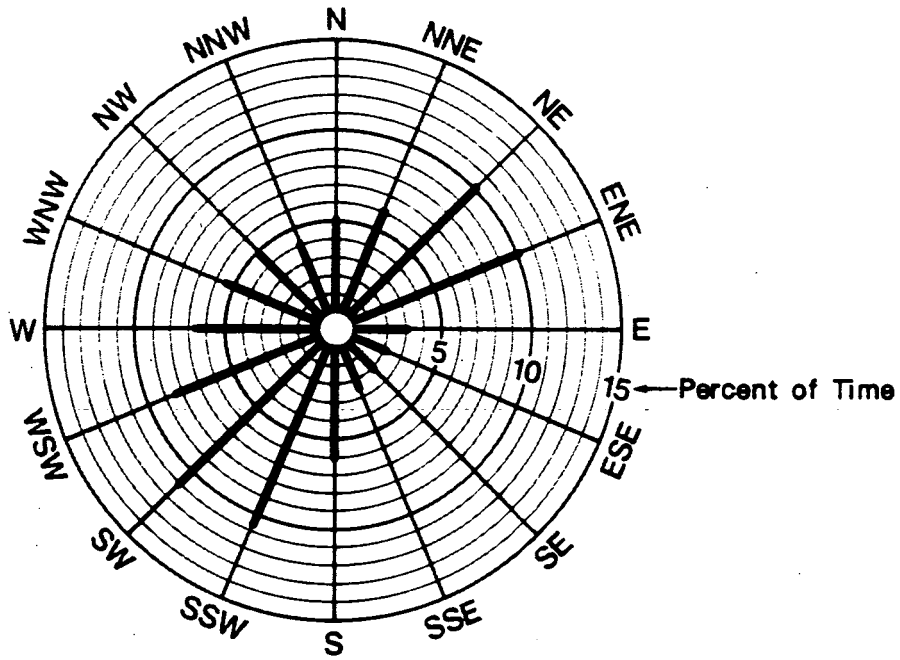
In addition to calculating the maximum dose to an individual, the FMPC used AIRDOS-EPA to calculate the cumulative radiation doses over the next 50 years — these doses are the committed doses — to persons within 80 km (50 miles) of the FMPC resulting from 1989 emissions. The committed effective dose due to 1989 airborne emissions was 63 person-rem (0.63 person-Sv). A person-rem is the collective dose to a population group. For example, a dose of one rem to 10 people results in a collective dose of 10 person-rem. As a comparison, the effective dose due to natural radiation per year for the same population group (population within 80 km) is 950,000 person-rem (9,500 person-Sv).

## Estimated Doses at the Air Monitoring Stations

Average air concentrations of uranium and other radionuclides measured at AMS 1 through 14 were entered into a variation of the AIRDOS-EPA model. Table 26 presents the estimated lung doses and effective doses that could be accumulated for the next 50 years




60 Meter Height Showing Direction from which the Wind Blows




10 Meter Height Showing Direction from which the Wind Blows

Figure 42. Wind Rose for the FMPC, 1989

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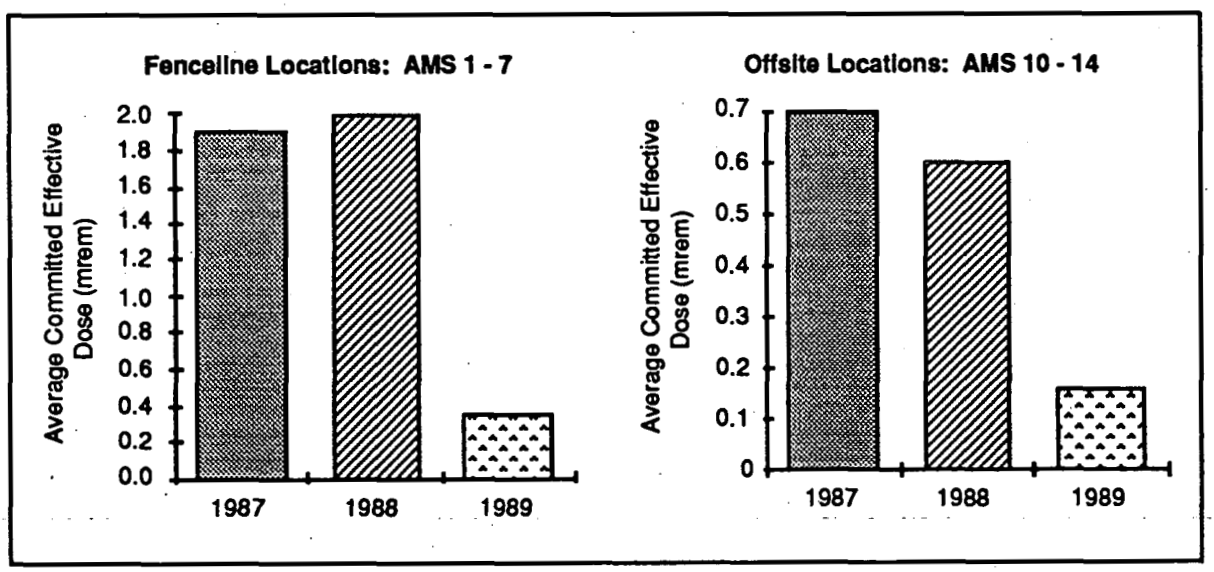
for a person breathing the air at any one of the stations 100% of the time during 1989.

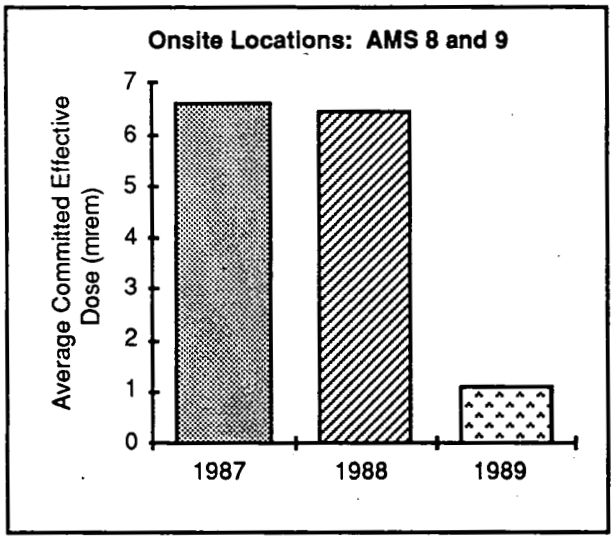
The results showed that the 1989 average committed effective dose at AMS 1 through 7 was 0.37 mrem (0.0037 mSv). AMS 3 had the maximum committed effective dose of 0.68 mrem (0.0068 mSv), while AMS 5 had the minimum committed effective dose of 0.24 mrem (0.0024 mSv). The maximum calculated fenceline pulmonary dose at AMS 3 (5.4 mrem, 0.054 mSv) was 7.2% of the NESHAP standard for organ dose.

The calculated average offsite committed effective dose at AMS 10 through 14 was 0.16 mrem (0.0016 mSv), with the maximum of 0.23 mrem (0.0023 mSv) at AMS 10 and the minimum of 0.14 mrem (0.0014 mSv) at AMS 12 and 13. These doses were a small fraction of the annual average background radiation dose of 360 mrem received by each member of the public living in the Greater Cincinnati area, and were considerably lower (more than 70% lower) than 1988 doses (Table 26).

In 1989, the FMPC installed air monitoring stations in Miamitown, Ohio (9.9 km or 6.1 miles from the site) and near the University of Cincinnati in Corryville, Ohio (24.8 km or 15.4 miles from the site). Data in 1990 from these stations are expected to provide background data against which to compare the data from the air monitoring stations near the FMPC.

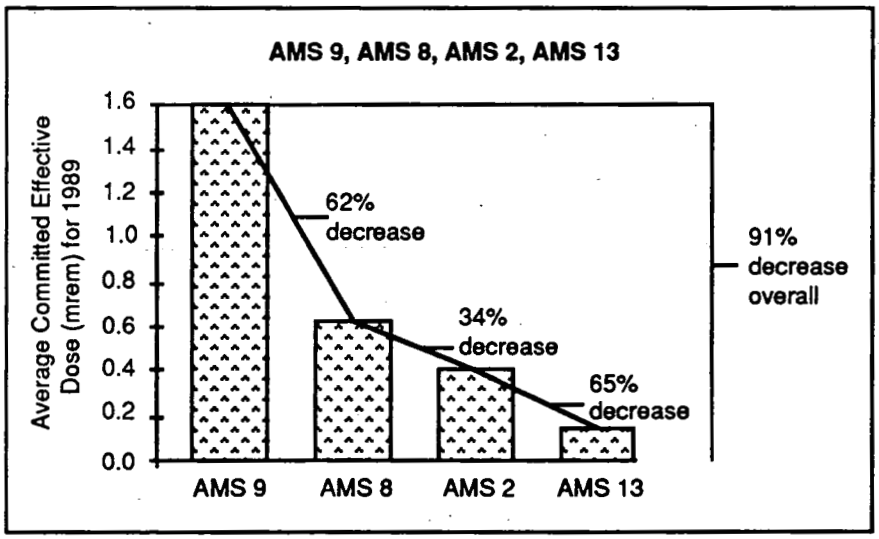


Even though the public does not have access to the onsite locations, AMS 8 & 9, the FMPC calculated the committed effective doses at those locations as well. The results were 0.61 mrem (0.0061 mSv) and 1.6 mrem (0.016 mSv) respectively.




By comparing the committed effective doses at AMS 8 & 9 with those at the fenceline and offsite stations, one can see how quickly the dose drops as the distance from the FMPC increases. For example, the committed effective dose decreased 62% from AMS 9 to AMS 8, 34% from AMS 8 to AMS 2, and decreased an additional 65% from AMS 2 to AMS 13. The committed effective dose decreased a total of 91% from AMS 9 to AMS 13. These air monitoring stations are in line sequentially outward from the process area in the prevailing wind direction, as shown in Figure 9.

This decrease occurs in part because the particles of uranium in the air emissions are relatively heavy (uranium is a heavy metal — about 19 times heavier than water and more than 50% heavier than lead). The uranium particles tend not to disperse as far or as uniformly as lighter particles might under similar conditions. Therefore, it would be expected that as distance from the FMPC process area increases, the concentration of uranium in the air would decrease rapidly. This expectation is supported by data collected at Air Monitoring Stations 9, 8, 2 and 13.



## Evaluating AIRDOS-EPA Results

One of the capabilities of the AIRDOS-EPA model is its ability to calculate doses at various locations around a facility using the combined measured plus estimated quantities of airborne radionuclides discharged. Also, if actual measurements of airborne radionuclide concentrations are made at a specific location, AIRDOS-EPA models can calculate doses at that location using either the emission data or the actual measured radionuclide concentrations. By comparing the doses obtained by the two methods, an evaluation can be made of how accurately the quantities of radionuclides released from unmeasured sources were estimated. If the dose calculated from the combined measured plus estimated amounts of emissions and the dose calculated from the actual measured airborne radionuclide concentrations are similar, then an accurate estimate was made for the unmeasured airborne emissions. If the doses are not similar, then the estimated emissions were not correct.

Since the FMPC measures actual airborne radionuclide concentrations at its continuously operating air monitoring stations, these measurements were used to evaluate how accurately the quantities of radionuclides emitted from unmonitored sources were estimated. The results of this evaluation are shown in the accompanying table.

The doses calculated with the estimated emissions from the pits excluded from the total emissions estimate agree quite well with the doses calculated from the actual airborne radionuclide concentrations measured at the air monitoring stations. In comparison, the doses calculated with the estimated pit emissions included in the total emissions estimate are in general much higher than the air monitoring station doses calculated from measured airborne concentrations. It is evident that an overestimation was made of the amounts of airborne radionuclides emitted from the pits since the air monitoring station doses calculated with the pit emissions included in the total estimated emissions are, in most cases, so much higher than the doses calculated from the actual measured radionuclide concentrations at these locations.

Since the quantities of radionuclides emitted from the pits were overestimated, the doses calculated using these values are

| ***Comparison of 50-year Committed Effective Dose Equivalents at Air Monitoring Stations*** | | | | | | |
|---|---|---|---|---|---|---|
| Effective Dose Equivalents (mrem) Based on | | | | Lung Doses (mrem) Based on | | |
| AMS | All Sources Included | Measured Concentrations | Pit Estimates Excluded | All Sources Included | Measured Concentrations | Pit Estimates Excluded |
| 1 | 6.9 | 0.33 | 0.44 | 45.3 | 2.5 | 3.6 |
| 2 | 3.0 | 0.40 | 0.69 | 20.3 | 3.2 | 5.6 |
| 3 | 4.3 | 0.68 | 1.7 | 30.3 | 5.4 | 13.9 |
| 4 | 1.6 | 0.27 | 0.73 | 11.1 | 2.0 | 5.3 |
| 5 | 1.1 | 0.24 | 0.57 | 8.3 | 1.8 | 4.6 |
| 6 | 2.2 | 0.40 | 0.63 | 15.0 | 3.1 | 5.1 |
| 7 | 1.3 | 0.27 | 0.23 | 8.5 | 2.1 | 1.8 |
| 8 | 5.3 | 0.61 | 1.3 | 36.5 | 4.6 | 10.6 |
| 9 | 8.1 | 1.6 | 1.9 | 55.4 | 13.2 | 15.3 |
| 10 | 0.29 | 0.23 | 0.15 | 2.1 | 1.8 | 1.2 |
| 11 | 0.20 | 0.15 | 0.091 | 1.5 | 1.2 | 0.7 |
| 12 | 0.069 | 0.14 | 0.026 | 0.5 | 1.1 | 0.2 |
| 13 | 0.52 | 0.14 | 0.21 | 3.7 | 1.1 | 1.7 |
| 14 | 0.50 | 0.15 | 0.21 | 3.5 | 1.2 | 1.7 |

erroneously high. In order to more accurately determine the radiation exposures to nearby residents and the population in general, the doses were recalculated using the AIRDOS-EPA model without the emissions estimated for the pits included in the calculations. Dose calculations were again made for the nearest resident in each of the 16 wind sectors to determine the maximally-exposed individual with the waste pit emission estimates excluded. The resident who received the maximum doses from airborne emissions in 1989 lives 1,030 meters (0.64 miles) east-southeast of the center of the FMPC production area. Sixty-five percent of the dose is due to emissions from the Laboratory Building (Building 15 in Figure 3), and 22% of the dose is due to emissions from Plant 8 (Building 8A in Figure 3).

The sum of the doses received over the next 50 years (committed dose) by every person within 80 km (50 miles) of the FMPC was

also recalculated. The maximum doses to an individual and the dose to the public, excluding waste pit emissions, are:

- 1.2 mrem (0.012 mSv) committed effective dose
- 9.6 mrem (0.096 mSv) to the lungs (pulmonary tissue)
- 21 person-rem (0.21 person-Sv) committed effective dose to the general population.

These doses reflect the true radiation exposures more accurately than the doses calculated with the estimated pit emissions included. This is so because doses calculated without the estimated pit emissions included in the total emissions estimate more closely match doses calculated from actual airborne radionuclide concentrations which are inherently more reliable than dose calculations based on estimates. In fact, the dose estimate based on concentrations measured at AMS 3 (the station closest to the maximally-exposed individual) is less than the dose estimate calculated by AIRDOS-EPA excluding waste pit emissions as shown in the previous table. Since production was suspended in July 1989, it is logical that the doses from FMPC operations in 1989 would be lower than 1988 doses. This is indeed the case when the estimated pit emissions are not included in the dose calculations.

# Additional Air Pathway Dose Calculations

In addition to using AIRDOS-EPA to calculate the maximum doses to the surrounding population, the FMPC calculated the estimated committed effective dose over 50 years that an individual could receive from eating produce grown near the FMPC and the dose from exposure to radon concentrations at the FMPC fenceline (Table 23). The following paragraphs explain how the FMPC determined these doses.

## *Estimated Dose from Eating Produce Grown Near the FMPC*

Since there are many private stands that sell produce grown on farms near the FMPC, this report estimated the maximum committed effective dose an individual could receive over 50 years from ingesting uranium in the produce grown on those farms during

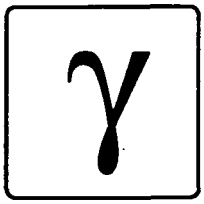
1989. To calculate this dose, the FMPC collected samples of produce grown within 3 km of the center of the site and analyzed them for uranium. The calculated committed effective dose of 1.7 mrem (0.017 mSv) is based on the conservative assumption that 100% of a person's diet of leafy vegetables (18 kg or 40 pounds) and above-ground vegetables (45 kg or 100 pounds) consisted of lettuce and green beans with the maximum measured uranium concentrations.[29]

## Estimated Dose from Radon

Since the early 1980s, when advancing technology made possible continuous, passive environmental radon monitoring, the FMPC has been monitoring radon and reporting measured concentrations, both at the FMPC fenceline and at background locations, in the annual Environmental Monitoring Reports. In the past few years, the radon monitoring program has expanded both the number of locations and the number of detectors deployed at each location. At the same time, the precision of the data received from the analytical laboratory that supplies and processes the detectors has also been improving. Prior to 1989, the precision of the radon data for the FMPC site fenceline had not been high enough to conclude that the radon concentrations measured were statistically distinguishable from background concentrations measured more than 25 km from the FMPC.

For 1989, however, the precision of the data has improved to the point where a small net radon concentration that is statistically distinguishable from background has been reported in Chapter Three. This concentration, $0.24 \pm 0.15$ pCi/l, is 8% of the DOE guideline for unrestricted areas and is a small fraction of the average indoor radon concentration recently reported for homes in the Cincinnati area (more than 50% of the 2,951 homes studied had levels of radon exceeding 2 pCi/l).[30] Some assumptions must be made in order to estimate the dose received from this concentration of radon. To be certain that the FMPC does not underestimate the dose, it is assumed that a person breathed air containing 0.24 pCi/l of radon continuously for an entire year and that radon decay products were in 50% equilibrium with radon. Using conservative lung exposure factors, the calculated effective dose equivalent for 0.24 pCi/l is 72 mrem/yr.[31] This can be compared to the average dose received from indoor radon of 200 mrem per year.

### *Estimated Dose from External Radiation*



There are many sources of external gamma radiation at the FMPC, but the primary concern for the public is the K-65 Silos. The FMPC calculated a dose for exposure to gamma radiation using thermoluminescent dosimeters (TLD) located at each air monitoring station. TLDs are small devices which can accumulate and store radiation dose information for many months. This provides an excellent method for measuring the dose received over long periods of time. The maximum annual gamma exposure of 17 μR/hr (17 μrem/hr) was measured at AMS 6, the station closest to the K-65 Silos on the west side of the site (Table 27).

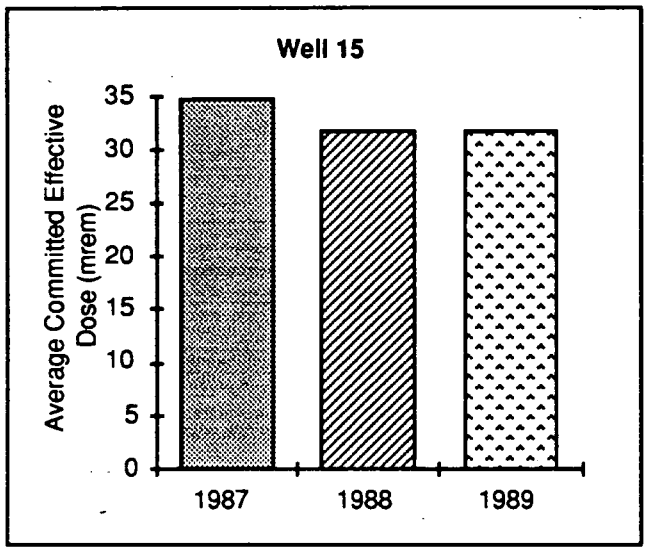
To assess doses from direct radiation to individuals living near the site, the FMPC used a pressurized ionization chamber to collect data at various locations around the FMPC. Several measurements were taken at control locations to obtain an average background gamma dose rate from natural sources. This value was determined to be 66 mrem (0.66 mSv) per year. Note that this was not the total background dose for this area, as shown in Table 23. The estimated annual external gamma dose to the resident living closest to the K-65 Silos was 12 mrem (0.12 mSv) above background, which is 12% of the DOE guideline. Again, this dose included the conservative assumption that the resident remained outside his home 100% of the time during 1989.

## Liquid Pathway Dose Calculations

Even though the liquid pathway is not the critical pathway for the FMPC, doses were calculated for a person obtaining all his or her drinking water from either the offsite well with the highest uranium concentration or from the Great Miami River at the FMPC outfall. These sources were used for dose calculations even though neither was used for drinking water. The FMPC also sampled and analyzed fish from the Great Miami River and calculated a dose from eating fish. The results are discussed in the following paragraphs.

## Estimated Dose from Drinking Groundwater from Well 15

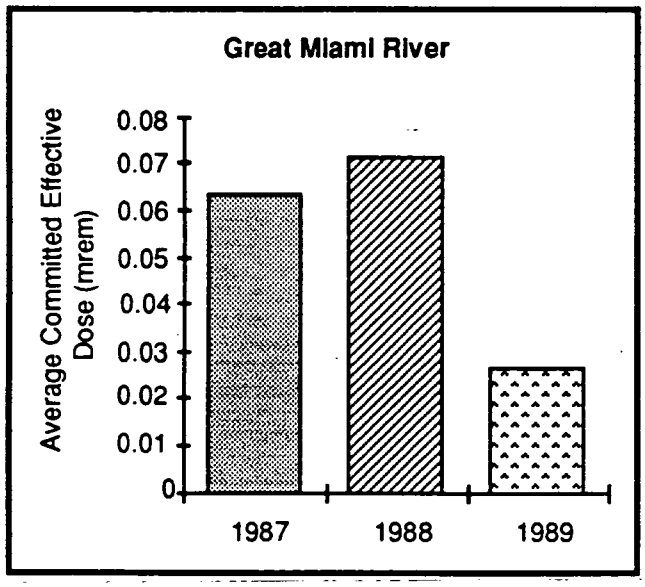
Well 15, which is located just south of the site (see Figure 39) and is not now used as a source of drinking water, had the highest average uranium concentration for offsite wells during 1989.




The committed effective dose an individual could receive over a 50-year period from drinking 2.0 liters (2.1 quarts) of water per day from well 15 during 1989 was calculated to be 32 mrem (0.32 mSv), which is 32% of the DOE guideline, and 520 mrem (5.2 mSv) to the bone surface, which is 10.4% of the DOE guideline (Table 23).[4]

## Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River is not designated as a public water supply by the OEPA, the FMPC estimated the radiation dose over a period of 50 years to an individual if, during the year 1989, that person drank only the water from the river at the FMPC effluent discharge point. A daily intake of 2.0 liters (2.1 quarts) could result in a committed effective dose of 0.027 mrem (0.00027 mSv), and a dose of 0.40 mrem (0.0040 mSv) to the bone surface.[32] The effective dose from drinking Great Miami River water is 0.7% of the proposed USEPA drinking water standard and 0.027% of the 100 mrem (1.0 mSv) DOE guideline for exposure to the public for all path-ways.



The doses (which are calculated using measured radio-nuclide concentrations in the effluent line) could vary due to fluctuations in flow rates of both the Great Miami River and the FMPC effluent line. These dose calculations assumed drinking river water that was mixed with FMPC effluent, and were based on average FMPC discharge and river flow rates.

## *Estimated Dose from Eating Fish from the Great Miami River*

As part of the ongoing sampling program, fish from the Great Miami River were sampled in September 1989 and analyzed for uranium. The data indicated that uranium concentration in fish collected at all three sampling locations decreased compared to 1988 concentrations. The fish sampling program is discussed in Chapter Three.

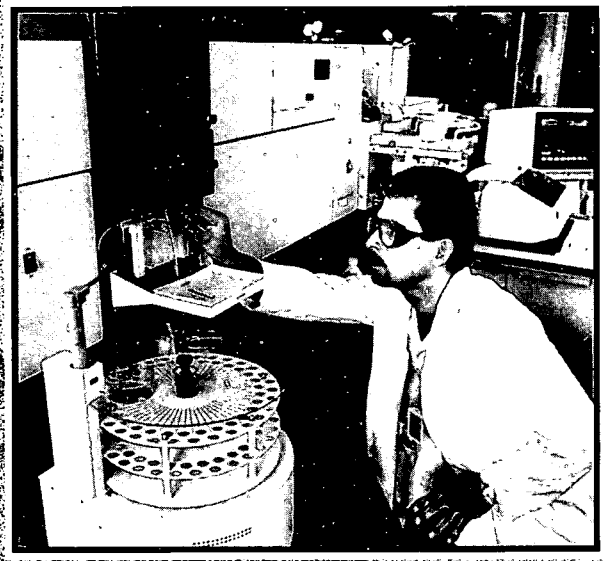
Using the uranium concentration data, the FMPC calculated the dose a person could receive from eating 4.4 kg (9.7 pounds) of fish caught near the FMPC outfall to the Great Miami River. That person could receive an estimated committed effective dose of 0.024 mrem (0.00024 mSv), and a maximum organ dose of 0.39 mrem (0.0039 mSv) to the bone surface. These doses were lower than those calculated from 1988 data, and were less than 0.03% of DOE guidelines.

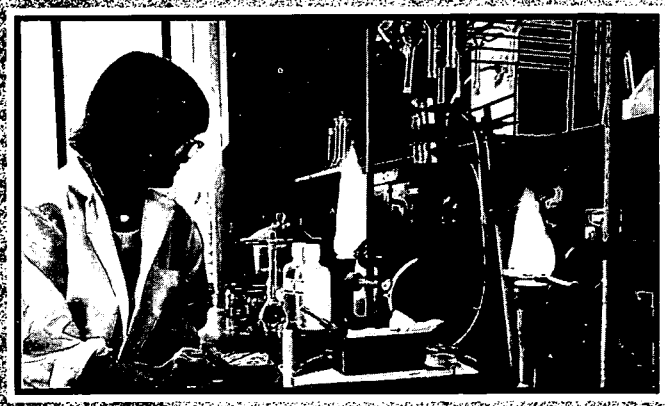
## SUMMARY

Radiation doses generated by the FMPC during 1989 were so small that they could not be measured directly but had to be inferred from careful measurements of various environmental parameters such as air, water, milk, fish, and vegetables (Table 23). From these measurements, and by making conservative assumptions to ensure the doses would not be underestimated, the FMPC used sophisticated computer modelling and made additional calculations to estimate possible doses to people living in the vicinity of the FMPC. The results of these calculations indicated that the radiation dose to nearby residents as a result of FMPC operations was a small fraction of the natural background radiation dose a person receives each year from natural sources.

# CHAPTER 5

# Quality Assurance for the Environmental Monitoring Program





CHAPTER FIVE

# Quality Assurance for the Environmental Monitoring Program

Acquiring reliable data is essential to demonstrating compliance with environmental regulations and making valid conclusions concerning environmental conditions. In order to assure that reliable data are obtained, the FMPC has developed comprehensive procedures which contain detailed instructions for performing environmental monitoring activities in a controlled and consistent manner. These procedures comply with applicable USEPA requirements, such as NPDES regulations, and generally accepted practices for conducting environmental monitoring programs.

To further assure that monitoring data are reliable, quality assurance measures are included in all procedures. Quality assurance measures are those actions and precautions taken to provide confidence that the resulting data are reliable. One example of quality assurance measures is the packaging of air filters in individual plastic bags to prevent contamination during transfer between the laboratory and air monitoring stations. Another example is the analysis of quality assurance samples containing known concentrations of chemicals or radionuclides along with field samples to check the accuracy of the analysis being performed. The FMPC Quality Department independently checks the performance of environmental monitoring activities for conformance to the quality assurance requirements contained in procedures. This is accomplished through a system of planned audits, surveillances and inspections.

Quality assurance for the overall environmental monitoring program is discussed in the following sections under the two general topics of field activities and sample analyses.

# Field Activities Quality Assurance

In order to conduct reliable evaluations of environmental conditions, the following criteria must be met:

- Measurements made in the field must be accurately performed with instruments calibrated against known standards according to accepted methods
- Samples which are collected must be representative of actual conditions in the environment
- Alterations of samples after collection must be prevented to the fullest extent possible until analyzed
- Results of field measurements and information pertinent to sample collection must be accurately recorded for subsequent evaluation and reference.

FMPC Environmental Monitoring (EM) procedures contain detailed quality assurance measures for meeting these criteria. These procedures specify step-by-step actions which must be followed when conducting EM field activities. Only trained personnel who have demonstrated proficiency in making field measurements and collecting representative samples are permitted to perform these functions.

QA measures for EM instrumentation include routine testing, maintenance and calibration to help ensure proper operation and accurate field measurements.

The sample collection process is checked by taking duplicates at random of various types of environmental samples. Proper sample collection is indicated when the analysis results for the duplicate samples are within acceptable limits. A significant difference in the results is evidence that a sampling or analysis problem exists. In such cases the cause of the difference is determined and corrective actions are initiated.

The reliability of the water sampling collection process is also evaluated by use of field and trip blanks. Field and trip blanks are prepared in the laboratory by filling sample containers with deionized water. Caps are placed on the containers and the trip blank is also sealed with tamper-evident tape. The blanks are placed with empty sample containers being taken by the sampling team into

the field. The trip blank remains sealed and the field blank is opened to the air while samples are being collected. When sampling is complete, the blanks are submitted along with the field samples for analyses. The analyses results for the trip blank detect contamination of the empty sample containers while results for the field blank serve to determine if airborne contamination entered the field samples during the collection process.

Once samples are collected, precautions are taken to prevent alteration of sample constituents until the time of analysis. Such precautions are necessary to prevent changes which can occur such as the conversion of nitrate to nitrite by microorganisms present in some samples, the loss of volatile compounds with increasing temperature, or the loss of trace metals from solution by absorption on sample container walls. Refrigeration or icing and the addition of chemical preservatives such as nitric or sulfuric acid are used to decrease volatility of compounds, control biological and chemical changes, and maintain trace metals in solution.

Since no preservation technique can completely stabilize samples indefinitely, limits are placed on the holding time which may elapse from sample collection until analyses are completed. The USEPA specified sample preservation methods and maximum holding times are followed for samples collected and analyzed to demonstrate compliance with regulatory requirements such as the FMPC National Pollution Discharge Elimination System (NPDES) permit. Where applicable, the USEPA specified sample preservation and handling methods are also applied to non-regulatory monitoring activities.

The handling of Environmental Monitoring samples from the time collected until delivered to the laboratory is controlled by chain-of-custody (COC) procedures. All personnel relinquishing and receiving samples are required to sign, date, and note the time on a COC record. COC documentation is required for those samples collected to evaluate compliance with environmental regulations, such as NPDES regulations, to assure that data generated from these samples are admissible as legal evidence. However, the custody of all other Environmental Monitoring samples is also controlled and documented according to the same COC procedures. This is done so that all EM data can be used as legal evidence, if necessary. Moreover, the application of COC requirements for all EM samples

assists in assuring that such samples are only handled by well-trained and knowledgeable personnel.

# Analytical Laboratory Quality Assurance

Quality assurance is an integral part of the FMPC Analytical Laboratories' operations. Laboratory QA consists of a structured program of actions taken to help ensure that reliable results are obtained when analyzing environmental samples. Laboratory QA is designed to:

- Make certain that analytical methodologies comply with USEPA protocol
- Provide a means to systematically and objectively evaluate analytical performance
- Identify problems so that they can be promptly corrected
- Detect and prevent the use of questionable data.

Day-to-day evaluation of the performance of FMPC laboratories is accomplished by means of quality assurance samples. Quality assurance samples include National Institute of Standards and Technology (formerly the National Bureau of Standards) reference materials, USEPA radionuclide solutions, compounds of precisely known purity, standardized reference solutions, duplicate field samples, and field samples to which known amounts of contaminates have been added.

The Operations Department Analytical Laboratories' Sample and Data Management group prepares the QA samples and submits them to the various onsite laboratories for analysis. At least 10% of the total number of samples analyzed are quality assurance samples which are processed along with the field samples.

The FMPC Quality Department evaluates the QA sample results and regularly submits reports to the laboratories for use in identifying potential areas of concern. If a significant problem is indicated, the Quality Department notifies the laboratories so that corrective actions can be taken and suspect results for field samples can be evaluated and rejected if warranted. In addition to analyzing quality assurance samples, the individual laboratories perform daily instrument

calibrations and stability checks and routinely analyze reagent blanks along with the field samples.

## Independent Evaluations of FMPC Laboratories

As described above, a comprehensive QA program is conducted by the FMPC Analytical Laboratories in conjunction with the Quality Department to help ensure that reliable results are obtained for environmental samples analyzed by onsite laboratories. In addition to this internal QA program, the FMPC laboratories regularly take part in several external QA programs conducted by outside organizations. Participation in external QA programs is a means of independently evaluating FMPC laboratory performance and provides added confidence that reliable results are being obtained for environmental samples.

External QA evaluations are conducted in the following manner. The organization conducting the evaluation prepares QA samples containing known amounts of a chemical or radioactive species. The known, or "true," amount of the species may be established by adding a precisely measured amount of the species to a substance which does not contain any of the species. For example, a QA water sample for fluoride analysis may be prepared by adding an accurately weighed amount of sodium fluoride to pure, deionized water. The true amount of the species may also be established by multiple analyses of an environmental material by one or more laboratories which have demonstrated the ability to perform accurate determinations. Since all soil contains some uranium, the true amount of uranium in soil to be used as a QA sample would be established in this way.

The QA samples, but not the known values of the test species, are distributed to the participating laboratories which analyze them and return the results obtained. The organization administering the program then provides a performance evaluation report comparing the laboratory's results to the true values of the test species. In most cases, the report also contains a comparison of the results obtained by the other participating laboratories. These comparisons show whether the laboratory's analyses are within acceptable limits of accuracy or that improvements are required.

One external QA program in which the FMPC participates is administered by DOE's Environmental Measurements Laboratory (EML). This program is conducted to evaluate the performance of laboratories which perform analyses to measure radionuclides in environmental samples. In this program, the FMPC receives and analyzes water and air filter samples for uranium and submits results for comparison to the results obtained by EML. In making the comparison, a ratio was computed by dividing the FMPC result by the EML result for each sample. The ratio would be 1.00 if the results agreed exactly.

The ratios for samples analyzed during 1989 are listed in Table 28.[33, 34] EML and FMPC results for the determination of uranium in two water samples were in excellent agreement since the ratios were 1.00 and 1.10 for the values obtained by each laboratory.

All air filter samples prepared by EML for use in each round of the DOE QA program contain identical amounts of each radionuclide. Thus, the results obtained by all laboratories can be compared to the single reference value established by EML for that radionuclide. Also, each laboratory is provided two air filter samples in each set of QA samples. Consequently, a laboratory may perform the same analysis on both filters and report two results for comparison to the one EML reference value.

The ratios of the FMPC results for the 89-04 air filter samples to the EML reference value were 1.64 and 1.75. There were three other laboratories which reported uranium results for the 89-04 air filter samples. The ratios of the results reported by these laboratories to the EML value ranged from 1.68 to 1.71. The EML uranium value for the 89-04 air filter sample is evidently incorrect since four different laboratories obtained higher but essentially equivalent results for their analyses of the sample.

For the 89-09 air filter samples, the ratios of the FMPC values to the EML reference value were 1.42 and 1.47. This indicates that the FMPC may have been overestimating the amount of uranium in environmental air dust samples. In order to more accurately measure the very low levels of uranium present in these samples, the FMPC laboratories began using a different and more sensitive method for measuring uranium in environmental air dust samples collected during 1990.

Another external QA program in which the FMPC participates is the Discharge Monitoring Report (DMR) QA evaluations. This program evaluates the ability of laboratories to measure nonradioactive contaminants in wastewater.

All laboratories which perform NPDES permit wastewater analyses are required to participate in the DMR QA program. Since NPDES samples are analyzed in-house, FMPC laboratories are included in this program. As stipulated by the USEPA, a corresponding QA sample must be analyzed for each parameter listed in the NPDES permit. The NPDES permit parameters which are measured by FMPC laboratories are discussed in Chapter Three under "Sampling Liquid Effluents." The USEPA evaluates the results for the QA samples only as satisfactory or unsatisfactory. All FMPC results submitted during 1989 were assessed as satisfactory by the USEPA (Table 29). The DMR QA evaluations of the performance of FMPC laboratories began in 1985. Only one analysis, a biological oxygen demand determination in 1985, was unacceptable during the five years the FMPC has participated in this external QA program.

The FMPC laboratories also participate in the Proficiency Environmental Testing (PET) external QA program. This is a voluntary program administered by a commercial vendor of analytical laboratory quality assurance services, and each laboratory pays a fee to participate. Each month the FMPC Sample and Data Management (SD&M) section submits PET samples to the various onsite laboratories which analyze them concurrently with field samples. Results obtained for the QA samples are compiled by the SD&M section and submitted for evaluation. A monthly evaluation report is then provided by the vendor comparing the FMPC laboratories' results to the reference values for each sample and to the results obtained by other laboratories participating in the PET program.

A summary of the performance of FMPC laboratories in the PET QA program during 1989 is provided in Table 30. For 28 of the 30 parameters analyzed, 92 to 100% of the results were within the USEPA acceptable criteria. Overall, 98% of the 719 determinations performed met these criteria. The use of this commercially-available service provides FMPC laboratories an additional resource for evaluating their performance so that any problems or errors can be detected and eliminated.

To further enhance the QA Program, the FMPC continued a split water sampling program with the Ohio Department of Health (ODH) which began in 1987. In many multilaboratory water analysis QA programs, the test samples are prepared in a laboratory rather than collecting them from the environment. The FMPC-ODH split sample program provides a means for comparing results obtained for samples actually collected in the field. To obtain split water samples, FMPC and ODH sampling team members alternately add a portion of the sample being collected to their individual sample bottles until the bottles are full. This collection method helps ensure that both water samples are as identical as possible. Split samples of surface and groundwater are collected and submitted to the FMPC and ODH laboratories for analysis of uranium and gross alpha and beta activity.

The FMPC did not receive the ODH results for samples collected during 1988 in time to be included in the 1988 EMR; the results are included in this report and are listed in Table 31. In comparing the results obtained by both laboratories for the same analysis, the ± uncertainty term provided with each result is taken into account. A result-range for each individual result is calculated by adding and subtracting the uncertainty term reported with the result. If the FMPC and ODH result-range for an analysis overlap, the two laboratory results are equivalent. Results obtained by both laboratories for the determination of uranium and gross alpha activity agreed very well since 92 and 93%, respectively, of the results reported for these analyses were equivalent. Agreement between the laboratories for gross beta determinations was only 84% for all 105 samples analyzed. However, the agreement for gross beta measurements improved with time: 92% of the results obtained by both laboratories for samples collected during the second half of 1988 were equivalent. In summary, FMPC and ODH laboratories obtained equivalent results for 90% of all split samples analyzed. This indicates good agreement between the laboratories considering that the samples were actual field samples rather than laboratory prepared QA samples.

## Contract Laboratory Quality Assurance

Because of the great number of analyses required to support all the various environmental monitoring activities, the FMPC uses commercial laboratories to supplement its onsite analytical

resources. Commercial laboratories must meet stringent requirements before being selected to provide environmental analytical services. To select the best qualified laboratory, a review of various QA specifications is conducted including personnel qualifications, analytical procedures, sample handling and preservation, data evaluation and record keeping, and requirements for precision, accuracy, and minimum detectable levels. Test samples are then sent to the candidate laboratories to evaluate their analytical capabilities. Onsite audits of the laboratories' facilities and operations are conducted by FMPC laboratory, procurement, and QA personnel before final selections are made. Upon selecting the laboratories, QA samples are submitted regularly with field samples in order to evaluate their performance on a continuing basis.

As part of the ongoing activities for evaluating the performance of contractor laboratories, the FMPC regularly sends QA samples along with field samples to the laboratory which analyzes air filter samples collected at offsite locations. Twenty-six QA air filter samples, prepared with amounts of uranium known only to FMPC, were submitted to the laboratory with 1989 field samples. The known amounts of uranium on the filters were in the range of the amounts normally present on field samples and varied by a factor of ten. Analytical results from the contract laboratory demonstrated an average error of slightly more than 12% for the QA air filters. This performance was considered satisfactory for analyses at environmental levels, although last year's average error was slightly less. Figure 43 shows the ratio of contract laboratory results to the FMPC known values for the 26 QA samples included with the 1989 field samples. The values ranged from 0.71 to 1.99 with an average of 1.12.

During 1989, the FMPC initiated the same quality assurance measures to evaluate the contractor laboratory's uranium analysis of milk samples. Figure 44 shows the ratio of the contract laboratory results to the known uranium values for the 12 QA milk samples analyzed with the FMPC 1989 field samples. The values ranged from 0.67 to 1.78 with an average of 1.11 which indicates adequate performance for this analysis. These QA programs will continue in 1990.

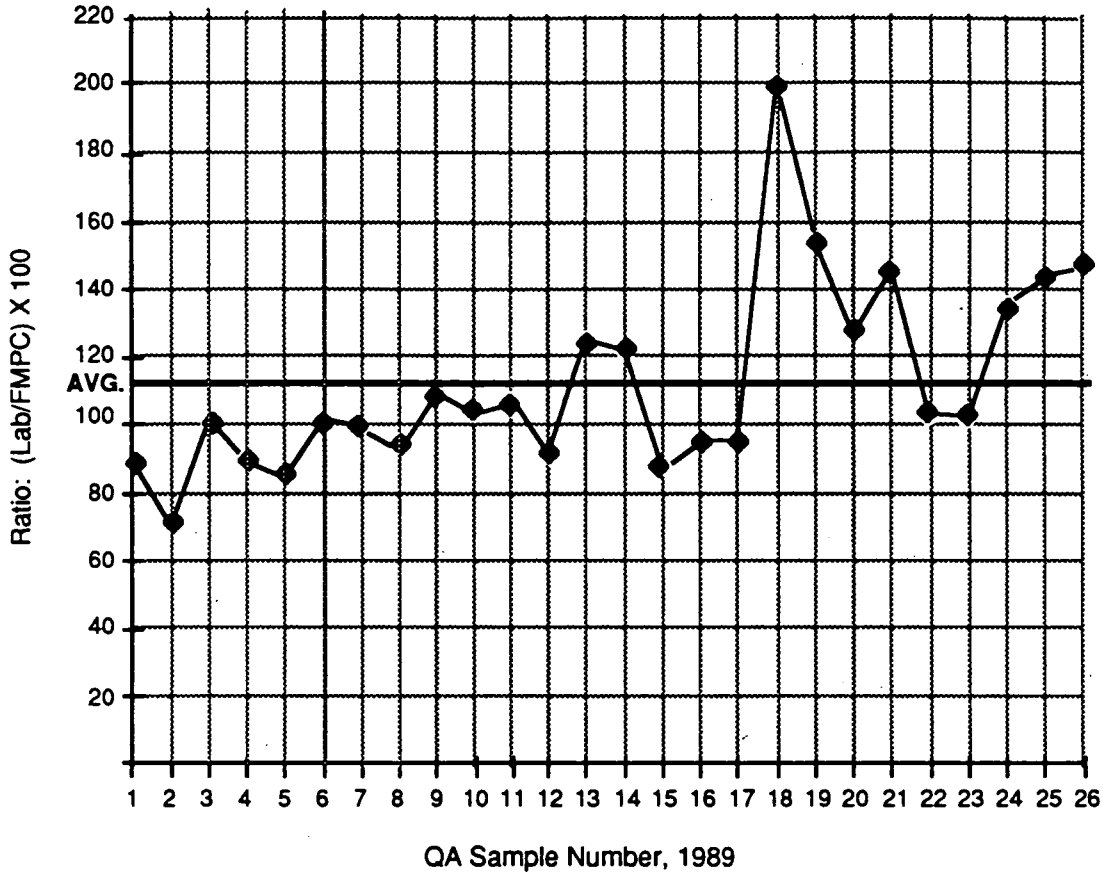



Figure 43. Air Filter Uranium QA Samples

# Data Evaluation, Reduction, and Reporting

Laboratory data were checked to assure that the analyses requested were performed and that the data provided appeared accurate. The data were reduced to a more meaningful and easy-to-comprehend form which can be tabulated or charted. Tabular data included ranges, averages, 95% confidence limits, and percent of guideline or standard. Comparisons between years were often made to indicate long-term trends. This information was evaluated and interpreted where possible. Plant operations, remedial activities, pollution control, analytical techniques, and incidents during the year were considered in the interpretation of the data.

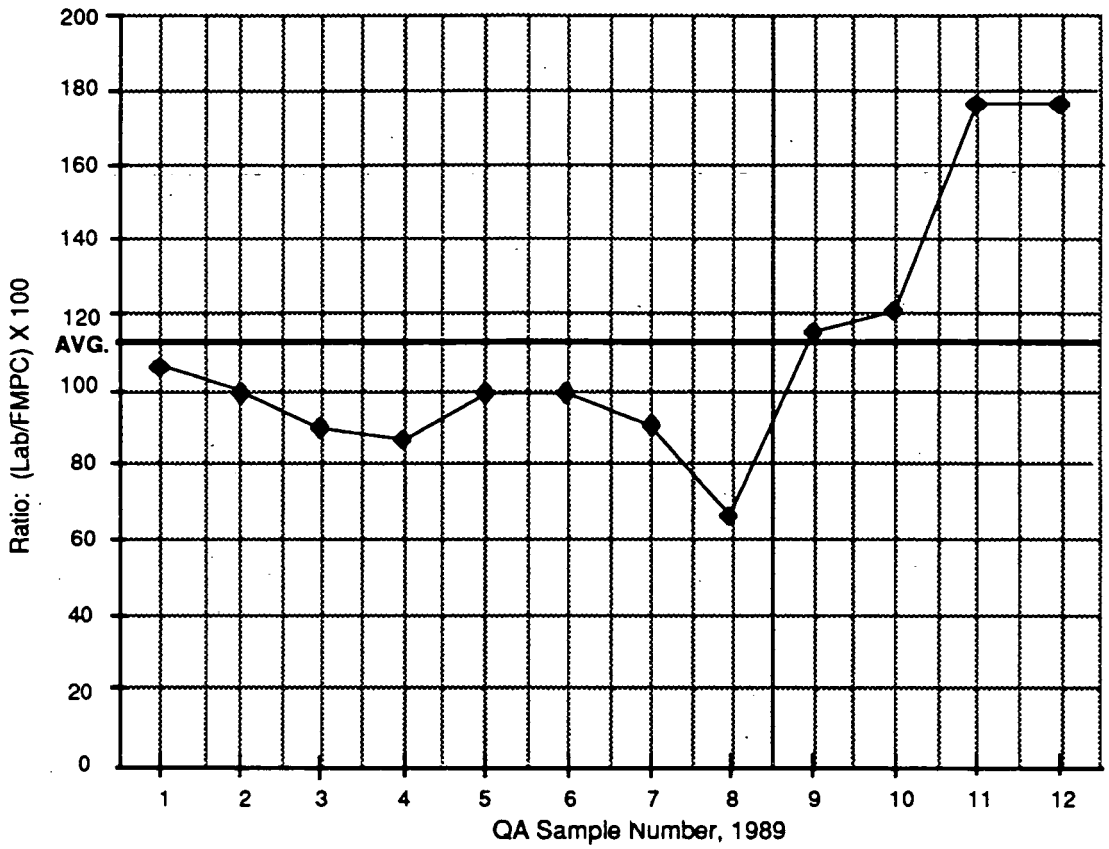


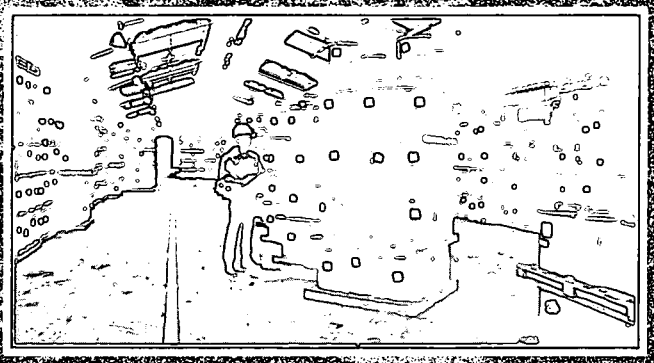

Figure 44. Milk Uranium QA Samples

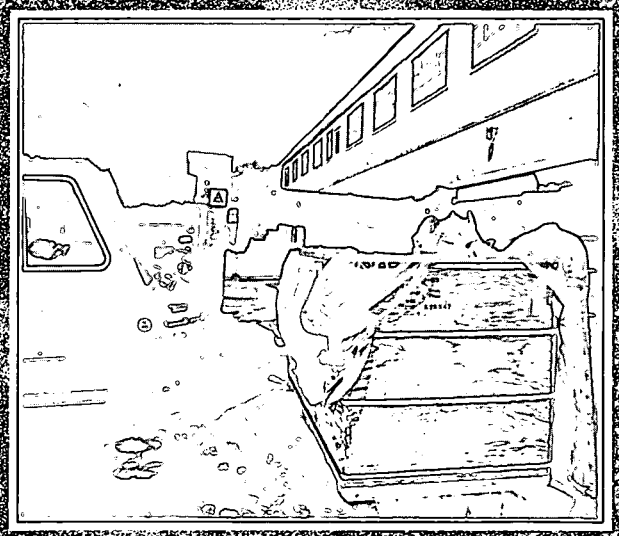
## SUMMARY

The acquisition of reliable data for environmental monitoring is a comprehensive program. Appropriate sampling procedures must be followed and proper analytical procedures practiced; data must be examined, validated, and presented in meaningful form; and results must be properly reported. The overall performance of the contract and FMPC laboratories, as determined by internal and external QA programs, was of a level which ensured that reliable monitoring data were obtained for determining compliance with environmental regulations and for making valid evaluations of environmental conditions. The next chapter describes the waste management activities at the FMPC.

# CHAPTER 6

# Waste Management Activities





CHAPTER SIX

# Waste Management Activities

Since stored wastes can potentially release pollutants into surface water, groundwater, air, and surrounding soil and sediments, waste management activities are a major element in FMPC environmental efforts. The purpose of this program is to eliminate such releases, and to minimize, control, and dispose of all wastes from the site which could release pollutants into the environment. This chapter highlights 1989 FMPC activities related to management of wastes within the production and administration areas of the site. Management of the wastes from past activities which are stored in FMPC pits, silos, and landfills is described in Chapter Seven.

The many diverse chemical and metallurgical processes used to produce uranium metal at the FMPC, along with the utility and administrative services that support production, have generated a wide variety of wastes that must be identified, treated, stored, and ultimately disposed. Recent accelerated cleanup activities and construction projects at the FMPC also generate significant amounts of wastes. The management of these wastes is governed by federal and state regulations with which the FMPC must comply.

## Categories of Waste at the FMPC

The wastes generated and stored at the FMPC can be grouped into three categories: low-level radioactive waste, hazardous or mixed waste, and conventional solid waste. Examples of types of waste are listed below:

**Low-level Radioactive Waste**

- Process residues (slags, neutralized raffinates, sump sludges)
- Sediments from the Stormwater Retention Basin and the Biodenitrification Surge Lagoon
- Scrap wood (pallets)
- Construction rubble
- Scrap metal (baled drums, process equipment, pipe)
- Sewage sludge

**Conventional Industrial Waste**

- Nonprocess trash
- Spent lime sludge
- Boiler Plant fly ash and water treatment sludges

**Hazardous or Mixed Waste**

- Contaminated cutting and cooling oils
- Solvent still-bottoms and sludges
- Barium Chloride salts
- PCB-containing materials
- Xylene
- Tributyl phosphate/kerosene
- Spent solvents
- Materials used to clean spills of waste covered under the Resource Conservation and Recovery Act (RCRA)
- Material containing lead, such as residue from sand blasting operations.

# Objective of the Solid Waste Program

The objective of the FMPC's Solid Waste Management Program is to dispose of, treat, or safely store solid wastes while complying with all applicable regulations. This objective covers both solid waste that is currently generated and that which was generated after the waste pits were closed but before offsite waste disposal shipments began. This latter waste is called backlog solid waste. The FMPC waste management areas are shown in Figure 45.

The FMPC's strategy for meeting this objective is:

- Pursue a waste minimization program
- Ship as much solid waste offsite as possible
- Maintain and upgrade storage facilities for solid waste that cannot be disposed of or eliminated
- Develop and implement programs to reduce disposal costs.

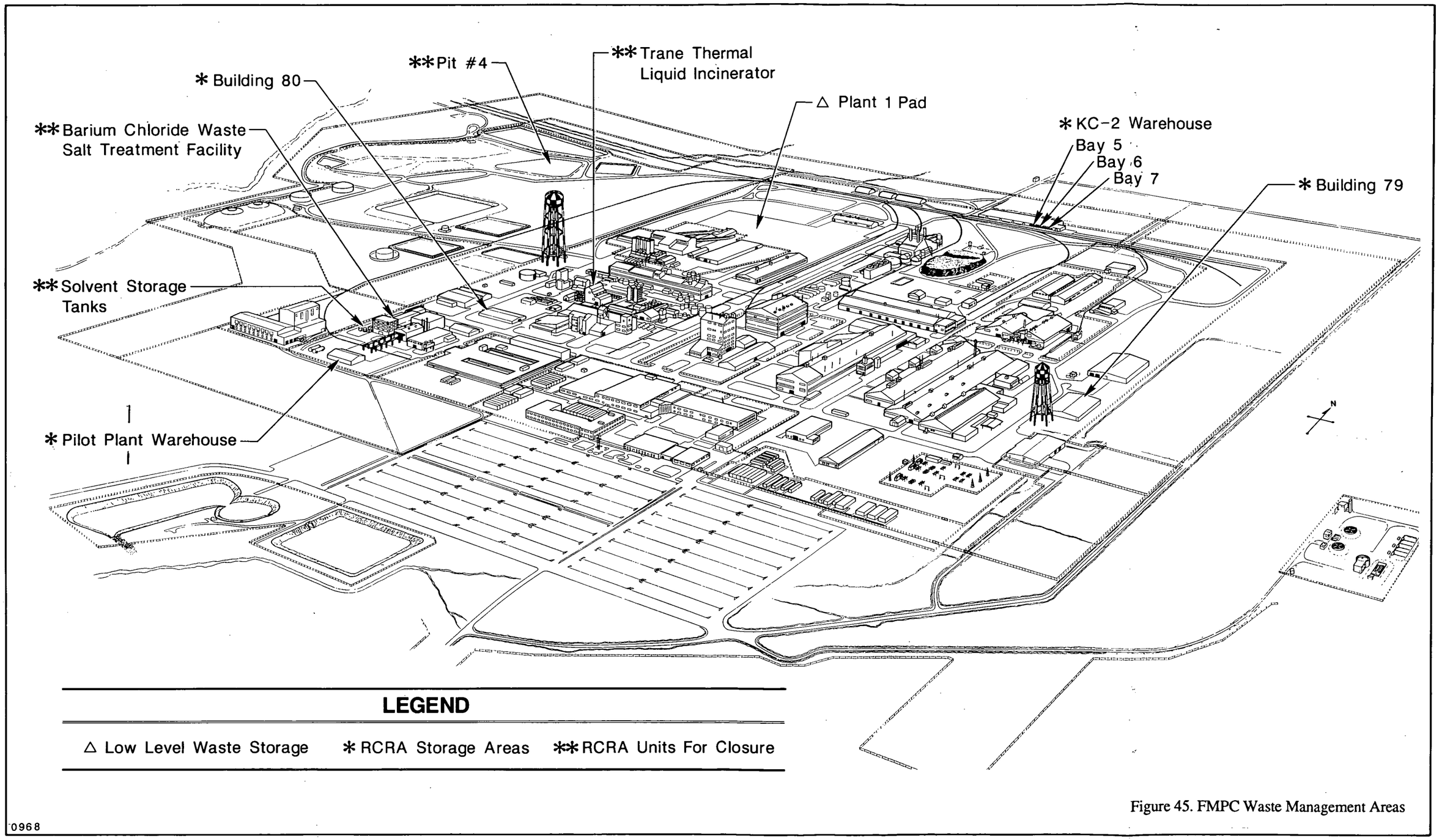



Figure 45. FMPC Waste Management Areas

# Low-Level Radioactive Waste Management

Low-level radioactive wastes are those materials contaminated with radionuclides, such as uranium, at concentrations which are not economically feasible to recover. These wastes are regulated under the Atomic Energy Act and can be disposed of only in designated radioactive waste disposal facilities. The principle disposal site for FMPC radioactive wastes is the Nevada Test Site (NTS). During 1989, a total of 13,000 cubic meters (459,343 cubic feet) of low-level radioactive waste was shipped to the NTS. This volume of waste would cover a football field to a depth of about 2.9 meters (9.5 ft).

The greatest volume of low-level radioactive wastes generated at the FMPC in the past has been residues and byproducts from the uranium production process. These wastes are in the form of sludges, filter cakes, slags, dust collector residues, and uranium metal chips or turnings from machining operations. Although uranium production operations were suspended in 1989, thus reducing the amount of new contaminated process residues, the adjustment of the economic discard limit (EDL) in late 1988 added to the volume of waste residues by classifying previously recoverable materials as wastes. The EDL is the amount of uranium that must be present in material to make it feasible to process the material to recover the uranium. Based upon the revised EDL, over 27,000 drum equivalents of residues once considered to contain recoverable amounts of uranium were categorized as waste.

**Low-Level Waste Shipment Data, 1989**

| Material Description | Cubic Feet |
|---|---|
| Scrap Wood | 49,781 |
| Magnesium Fluoride | 368 |
| Baled Trash | 35,053 |
| Filter and Sump Cake | 30,496 |
| Refuse Metal | 61,450 |
| Dust Collector Residues | 2,397 |
| Incinerator Ash | 1,304 |
| Construction Rubble | 252,422 |
| Asbestos | 18,784 |
| Graphite | 7,288 |
| **TOTAL** | **459,343** |

Other low-level wastes include items used in the production process which have become contaminated with uranium and which cannot be decontaminated or used again. These items include metal drums, wooden pallets, and trash such as rags, paper, and wood. Since production was suspended, the majority of wastes are now generated from cleanup and other environmental restoration activities and renovation projects. These wastes include contaminated soil,

concrete, rubble, scrap metal, wood, and trash, which, because of their contact with uranium, have become contaminated and must be disposed of as low-level radioactive waste.

## Storing Low-Level Wastes

Because the low-level radioactive wastes and uranium residues are no longer going into onsite disposal pits or being processed to recover uranium, they are stored in drums outdoors on the Plant 1 Pad for extended periods. These drums and other containers may corrode and potentially leak. To prevent further deterioration of the waste containers and potential releases of contaminants, a major overpacking effort began during 1989. Overpacking means putting the waste in a 48-gallon drum then placing that drum inside a 55-gallon drum. Over 5,000 drums of low-level radioactive waste and residues have been overpacked, re-drummed, and/or moved into better storage locations.

## Scrap Metal Activities

Scrap metal is radiologically surveyed at the point of generation. If it is uncontaminated and potentially usable, it is stockpiled for shipment to local scrap dealers or for use elsewhere at the site. Contaminated scrap metal that cannot be used again at the site is packaged and shipped offsite for disposal.

During 1989, about 160 tons of scrap metal was decontaminated to levels suitable for unrestricted release. This FMPC decontamination effort was given the "Waste Minimization Award" by DOE in 1989. This program was created by DOE to recognize outstanding achievements in waste minimization programs.

The FMPC is also storing about 1,350 tons of scrap copper on a concrete pad in the northwest part of the site. The copper scrap, consisting mostly of motor windings, was transferred to the FMPC as a result of an upgrade of other DOE facilities during the 1970s.

# Conventional Solid Waste Management

The FMPC also generates nonradioactive wastes normally associated with a large industrial facility: boiler plant waste, nonprocess trash, and potable-water treatment sludge.

The Boiler Plant produces fly ash, sludges from boiler water treatment, and runoff from the coal pile. Fly ash is taken to the southwest corner of the site. A cover will eventually be placed over the fly ash pile to prevent water runoff and air dispersal. The boiler plant water sludges and coal pile runoff are currently drained to a retention pond, and from there the water goes to the General Sump for treatment.

The FMPC drinking water is treated with water softeners. The lime from this process is collected in sludge beds on the western side of the site. These beds are nearly full. Options are being studied to address this problem, as well as the overall problem of how to dispose of all types of conventional solid waste.

# Mixed Waste Management

The third major category of waste at the FMPC is mixed radioactive/hazardous waste, referred to as mixed waste. These wastes are regulated under the Atomic Energy Act and the Resource Conservation and Recovery Act. RCRA was passed in 1976, along with subsequent amendments in the 1980s, to address a problem of enormous magnitude — how to safely dispose of the huge volumes of municipal and hazardous waste generated nationwide. The goals set by RCRA are:

- To protect human health and the environment
- To reduce waste and conserve energy and natural resources
- To reduce or eliminate the generation of hazardous waste as expeditiously as possible.

## *RCRA Permit Applications*

In September 1988, the USEPA published new rules on the permitting of facilities that treat, store, or dispose of mixed waste.

These rules allow owners and operators of facilities handling mixed wastes to submit a modified RCRA Part A Permit Application to the USEPA by March 1989 in order to continue to operate a hazardous waste facility until a final permit is issued. The FMPC currently has this interim status with the State of Ohio. Because the FMPC has a large amount of radioactive wastes that may contain various RCRA-regulated constituents due to past processing operations, the FMPC submitted a revised RCRA Part A Permit Application to the USEPA and OEPA on March 22, 1989. This modified application significantly expanded and encompassed a greater variety of waste streams regulated by RCRA. In addition to listing FMPC waste streams and waste management units, the application also defined current and planned storage facilities needed to safely store these wastes at the FMPC.

An extensive revision of the FMPC's RCRA Part B Permit Application was also completed and submitted in September 1989. A RCRA Part B Application is the detailed description of how a facility will comply with specific hazardous waste management requirements set forth in the federal regulations.[35, 36] Upon final approval, the Part B Permit Application becomes the actual operating permit for a facility. The original FMPC Part B Permit Application was submitted in 1985, and some sections have been revised during the past four years. However, in order to comply with the new requirements for mixed wastes and maintain interim status, the FMPC revised the entire Part B Permit Application. An eleven-volume document detailing the FMPC RCRA waste management program was submitted to the USEPA and OEPA. The new Part B application accomplishes several goals: it details information from the Part A application, it updates the FMPC's waste analysis plan for mixed wastes, it details the site's Remedial Investigation/ Feasibility Studies for hazardous waste management units including groundwater monitoring programs, and it includes a RCRA Contingency Plan for hazardous waste emergencies.

## RCRA Contingency Plan

A RCRA Contingency Plan was submitted as part of the Part B Permit Application to ensure that specific planned procedures exist for hazardous waste handling and storage at the FMPC in the event that emergency situations occur. Previously, the FMPC had used the FMPC Spill Prevention Control and Countermeasures Plan

(SPCC) and the FMPC Emergency Plan to meet the emergency planning requirements of RCRA. The current RCRA Contingency Plan is designed to minimize hazards to human health or the environment from fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or surface waters at and around the FMPC. It establishes policies, procedures, prevention and countermeasures to minimize adverse effects from any of the above emergency situations. The RCRA Contingency Plan was prepared and distributed in September 1989 to both the USEPA and OEPA, all FMPC site organizations, and to outside organizations having emergency mutual aid agreements with the FMPC.

## *Hazardous Waste Incidents at FMPC*

Two incidents occurred in 1989 involving releases of hazardous wastes stored at the FMPC. Neither instance involved a threat to individuals in areas offsite of the FMPC, and no injuries occurred to personnel onsite. Both events were reported to regulatory agencies as required under federal and Ohio laws.

### Pinhole Leaks in Tank T-5

In June 1989, two pinhole leaks were discovered in tank T-5 at the Pilot Plant facility within the FMPC. This tank stored about 30,300 liters (8,000 gallons) of a spent 1,1,1-trichloroethane from the distillation of solvent shipped to the FMPC in 1979. The material had been distilled in 1984, identified as hazardous waste, and subsequently stored in two bulk tanks at the Pilot Plant. The leaks were from corroded areas in welds measuring about 1.3 cm (1/2 inch) in diameter. The areas were damp at the point of the pinhole but there was no evidence of dripping or releases from the tank into the surrounding diked area. To correct the problem, patches were immediately placed over the corroded areas of the tank.

The spent solvent was subsequently removed from both Pilot Plant tanks and stored in 55-gallon drums at an inside warehouse having diked floors. Both the USEPA and OEPA were advised of the incident and the corrective actions taken.

### Underground Storage Tank Investigation

The second incident involved an underground storage tank (UST) located at the FMPC Transportation Garage. Waste petroleum

products from past motor vehicle maintenance activities had been separated and collected in a 200-gallon underground waste oil tank (tank 5). This tank had been out of service since 1985. As part of the efforts to evaluate and remove all underground storage tanks at the FMPC, work began in late September 1989 to sample the fluid remaining in this tank. During the excavation to reach the capped, buried pumpout pipe to the tank, the pipe was accidentally damaged. A small pool of standing water having a slight petroleum sheen and odor was noted in the excavation.

Following Ohio UST requirements, the Ohio Fire Marshall's Office was notified through DOE of a suspected petroleum release. Soil samples indicated the presence of petroleum hydrocarbons. The tank was found to be full of a clear liquid, which was completely removed and sampled for petroleum and RCRA-regulated constituents. Results confirmed the presence of 1,1,1 - trichloroethane and 1,1 - dichloroethane, both cleaning solvents used at the FMPC. As a result, the USEPA, OEPA, and Ohio Fire Marshall's Office were notified that the tank was confirmed to have contained RCRA-regulated hazardous substances. Additional soil samples were taken to help determine the extent of soil contamination in the vicinity of the tank. A closure plan is now being developed and will be sent to the OEPA for the removal of both tank 5 and soil contamination discovered around the tank.

In February 1989, 13 underground petroleum storage tanks were registered with the Ohio State Fire Marshal as specified by state underground storage tank regulations (Table 32). This list was based upon the best information available at the time. In June 1989, a permit application for the removal of 10 tanks was issued to the State Fire Marshal.

Tanks 1, 2, and 3 were operating at the beginning of the year. In April 1989 a suspected release from tanks 1 and 2 caused these tanks to be taken out of service, leaving tank 3 as the only tank in-service at the year's end. The suspected release was neither confirmed nor disproved in 1989.

## Groundwater Monitoring – RCRA Assessment

As mentioned in the groundwater section in Chapter Three, the FMPC conducted six rounds of groundwater sampling from August

1985 to December 1987 as part of the RCRA Detection Program. Comparisons of data from designated wells that are both upgradient and downgradient of waste pit 4 indicated that statistically significant changes had occurred downgradient in some indicator parameters.

Once the results were confirmed by additional sampling, the FMPC began the second required action in November 1987 by submitting a groundwater quality assessment program plan to USEPA. This plan, which called for the assessment program to be included as part of the site-wide RI/FS investigation, was developed to satisfy federal regulations.[37]

The USEPA commented on the assessment plan in early 1989. In March 1989, the FMPC submitted a revised Groundwater Quality Assessment Program Plan to the USEPA which incorporated their comments.[38]

| Upgradient Till Wells | Downgradient Till Wells | Upgradient Sand & Gravel | Downgradient Sand & Gravel |
|---|---|---|---|
| 1024 | 1004 | 2043/3043 | 2010/3010/4010 |
| 1052 | 1025 | 2066/3066 | 2013/3013/4013 |
| | 1027 | | 2019/3019 |
| | 1028 | | 2021 |
| | 1030 | | 2027 |
| | 1031 | | 2037/3037 |
| | 1038 | | 2051/3051 |
| | 1072 | | 2055/3055 |
| | 1074 | | 2084/3084 |
| | 1079 | | 3001/4001 |
| | 1080 | | 3008/4008 |
| | 1081 | | 3024 |
| | 1082 | | |
| | 1083 | | |

Under the new plan the RCRA assessment monitoring is conducted separately from the RI/FS program. Forty-three wells, which were installed under the RI/FS program, were selected for the assessment monitoring (Figure 46). The wells are organized into four categories according to their relationship to waste pit 4: upgradient till wells, downgradient till wells, upgradient sand and gravel, and down-gradient sand and gravel. These wells are sampled on a quarterly basis for general water quality indicators, radionuclides, and site-specific parameters. These 43 RCRA assessment wells are also sampled every year for inorganics, volatile organics, semi-volatile organics, and pesticide organics from the

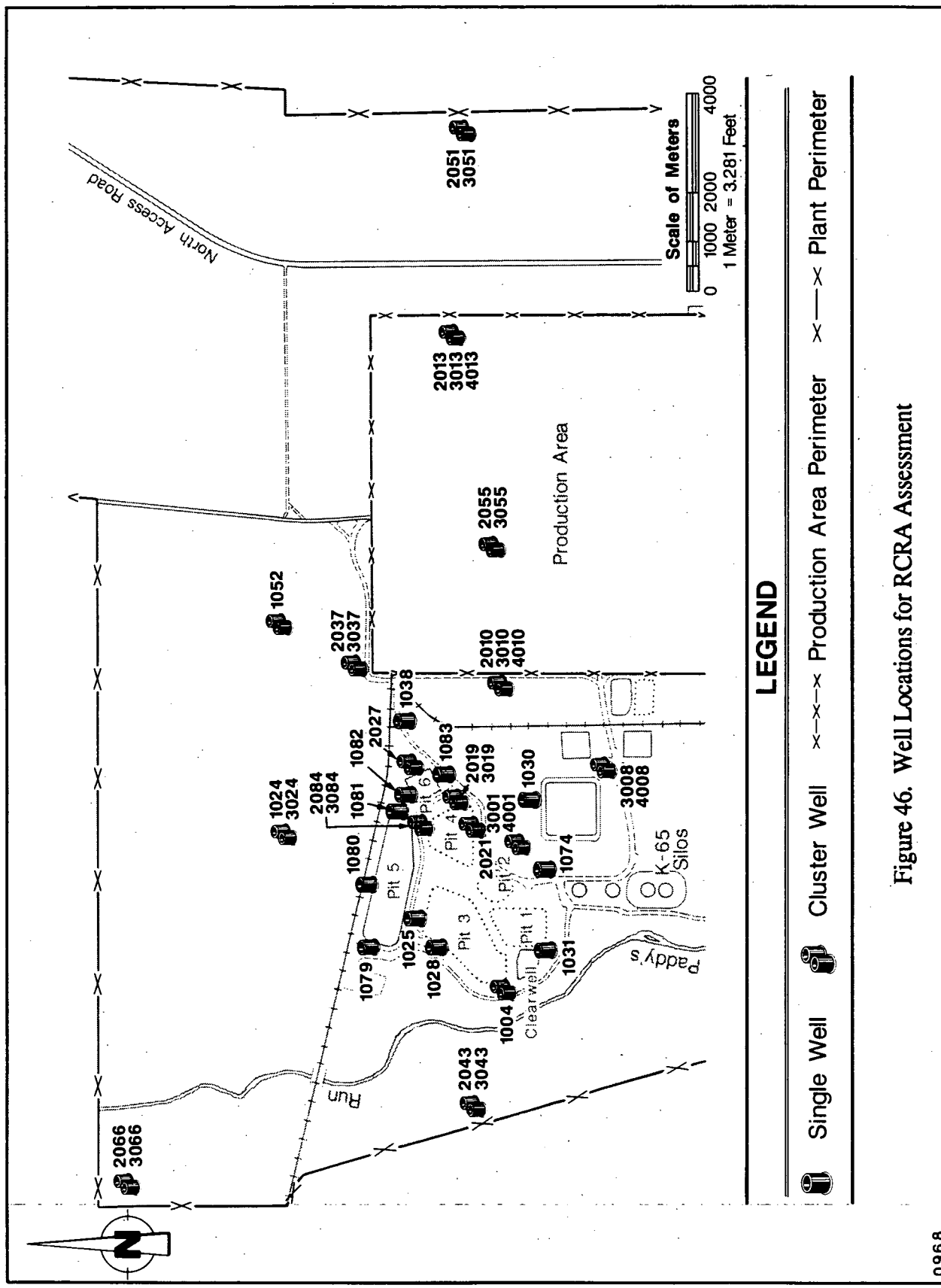



Figure 46. Well Locations for RCRA Assessment

extended Hazardous Substance List (HSL). A list of the site-specific parameters and HSL constituents can be found in Tables 33 and 34.

## Performing RCRA Closures

Buildings and equipment that are contaminated with RCRA contaminants must be decontaminated to limits set by OEPA. This is known as a RCRA closure. If buildings or equipment are to be used again rather than simply removed from service, they must be cleaned to more stringent standards as specified by the OEPA. The following paragraphs describe two of the RCRA closures at the FMPC.

### The Barium Chloride Waste Salt Treatment Facility

This facility operated from December 1985 through March 1986 as a pilot-scale operation to convert water-soluble barium chloride to water-insoluble barium sulfate. The 75' x 50' facility, located inside the Pilot Plant, included four stainless steel tanks (Figure 45). About 8,400 kg (18,500 pounds) of barium chloride were treated.

For this RCRA closure, the equipment and piping was decontaminated and will be removed from the building.[39] Since the floor of this facility may be used as a storage space, the OEPA established additional cleanup requirements as stated in a rinseate sampling plan.[40] One of the requirements is that deionized water be poured over the floor then sampled for RCRA constituents. The data were compared to OEPA established limits which were one hundred times more stringent (actually below drinking-water standards) than the RCRA EP Toxicity standards. The results indicated that none exceeded OEPA standards for drinking water. This project was completed in February 1990.

### The Trane Thermal Liquid Incinerator

A second RCRA closure that began during 1989 is the Trane Thermal Liquid Incinerator, located near Building 39A (Figure 45). This incinerator, which operated periodically between 1980 and 1986, burned waste oils generated at the FMPC. The burn rate for the incinerator was about 26 liters (7 gallons) per hour. Although it is not known what types of oil were burned in the incinerator, oils that were stored next to the incinerator were analyzed and found to include lead and 1,1,1-trichloroethane, both of which are RCRA

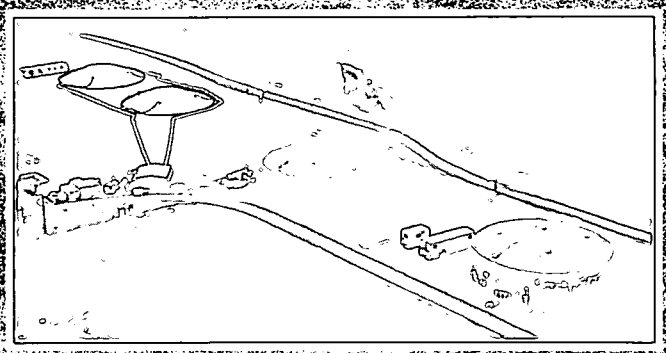
hazardous wastes. The FMPC is revising this closure plan by adding equipment to be decontaminated.

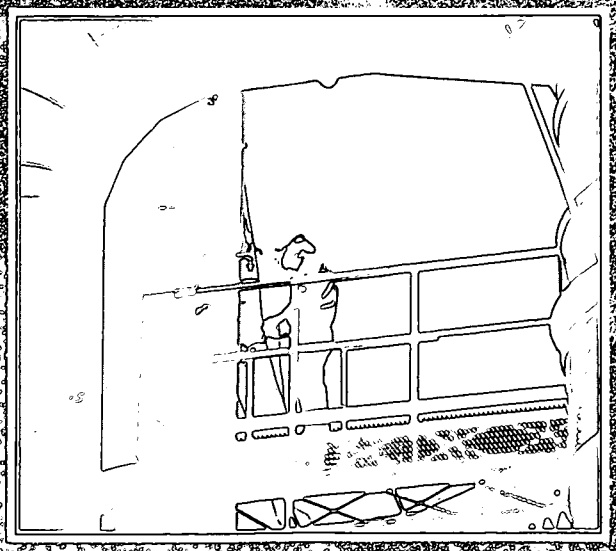
## SUMMARY OF WASTE MANAGEMENT ACTIVITIES

The FMPC continues to make significant progress in shipping waste offsite. In addition the FMPC has renewed its emphasis on complying with RCRA waste regulations. These actions have significantly reduced the potential for environmental problems related to waste management activities. The FMPC has been making significant improvements in several additional areas and this progress is described in the following chapter.

# CHAPTER 7

# Special Studies and Significant Events





CHAPTER SEVEN

# Special Studies and Significant Events

In addition to the ongoing data collection and analysis performed as part of the routine Environmental Monitoring Program at the FMPC, several additional studies were performed and environmental restoration projects undertaken during 1989, including:

- Remedial Investigation and Feasibility Study and related projects
- Water-compliance activities
- Air-compliance activities.

Furthermore, the FMPC responded to spills and releases of radioactive materials called unusual events. These are discussed at the end of this chapter.

## Remedial Investigation and Feasibility Study and Related Projects

A comprehensive environmental Remedial Investigation and Feasibility Study (RI/FS) is underway at the FMPC. The study is being conducted for DOE in cooperation with USEPA and OEPA. Detailed information about the RI/FS is provided in the Administrative Record, which is available for public review both at the FMPC and the Lane Public Library in Hamilton, Ohio. The Administrative Record is the inventory of documentation for the RI/FS project. This EMR presents general information about the program, and is not intended to provide details of nor interpret data collected as part of this extensive undertaking.

The RI/FS, which began in July 1986, is designed to investigate the nature and extent of potential environmental impacts from past and current operations at the FMPC. Based upon the results of this investigation, the RI/FS will then develop and evaluate alternatives to solve the environmental problems.

## RI/FS: A Brief Definition

A RI/FS is a comprehensive environmental investigation conducted in a systematic fashion according to strict USEPA regulations and guidelines. It is broken into two distinct, yet inseparable phases: the Remedial Investigation (RI) and the Feasibility Study (FS). During the remedial investigation phase, a broad-based study is completed to evaluate existing environmental and public health risks associated with past or existing facility operations. These risks are then compared against existing regulatory standards and guidelines to identify potential environmental problems and concerns that must be considered for corrective actions. In addition, comprehensive field investigations are conducted according to a USEPA approved work plan.

The Feasibility Study phase of the RI/FS process develops and evaluates corrective action alternatives to mitigate identified environmental concerns. The Feasibility Study recommends one or more final remedial alternatives for consideration by the USEPA in its final selection process. Following selection of the alternatives, a Record of Decision will be issued by USEPA formally documenting the decision.

## The Remedial Investigation: Identifying Problems

DOE has contracted with an independent environmental firm to conduct the RI/FS. This contractor samples surface soils, sediments, groundwater, surface water and biological resources, both onsite and in the vicinity of the FMPC. In order to better understand the environmental setting at the FMPC and to supplement previous data, the RI/FS team focused on the following sampling programs during 1989:

- Groundwater Investigations
- Surface Water and Sediment Sampling
- Production and Additional Suspect Area Investigations.

### Groundwater Investigations

The Groundwater Monitoring Program for the RI/FS is designed to refine the understanding of the hydrology of the FMPC and to investigate potential impacts of the facility on regional groundwater quality. As part of the RI/FS, the FMPC has installed more than 120 wells, both onsite and offsite. These new wells, along with

existing wells, were sampled on a quarterly basis and analyzed for a full series of radiological and general water-quality parameters. The FMPC has received the results from five rounds of samples as of December 31, 1989. Sampling on select wells continues.

Data confirm the presence of three isolated areas of above-background concentrations of uranium in the regional groundwater aquifer. One area is located directly beneath the FMPC Waste Storage Area, the second is to the south of the FMPC, and the third is beneath the FMPC production area.

Groundwater flow in the regional aquifer beneath the FMPC Waste Storage and Production Areas is directed east toward the Great Miami River. No above-background concentrations of uranium or other hazardous substances have been detected offsite to the east. The above-background concentrations of uranium in the regional aquifer beneath the Waste Storage and Production Areas present no near-term threat to onsite or offsite populations.

The above-background concentrations of uranium in groundwater are confined to an area near the south boundary of the FMPC. Groundwater flow at this location is directly south along an ancient buried stream bed. Groundwater investigations continued in this area during 1989 with the installation and sampling of 10 monitoring wells. Investigations will continue during 1990 to provide information to ongoing groundwater modeling and feasibility study activities. Efforts are underway to begin near-term corrective actions in the south contamination plume that will address problems until final actions are set in motion through the RI/FS process.

In May 1989, an isolated RI/FS shallow monitoring well located about 2.4 km (1.5 miles) south of the southern boundary of the FMPC was found to contain above-background concentrations of uranium (generally less than 14 pCi/l or 20 ppb). This is significant because the well is about 300 meters (1,000 feet) beyond the leading edge of the south groundwater contamination plume and is on the western bank of Paddy's Run. Since the exact cause of these elevated concentrations is not known, additional sampling will be performed at this well during 1990.

### Surface Water and Sediment Sampling

Data from the samples collected during 1989 were consistent with data collected as part of the FMPC Environmental Monitoring

Program. In general, the data did not indicate any significant above-background concentrations of radionuclides in either the surface water or sediment samples collected from Paddy's Run.

**Production and Additional Suspect Area Investigation**

The purpose of the RI/FS Production and Additional Suspect Area Investigation is to determine the nature and extent of any hazardous or radiological constituents that may exist in the environment within the FMPC Production Area. The program is also investigating FMPC facilities suspected of past release or disposal of hazardous substances.

Based on the history of FMPC production operations, more than 260 borings were proposed in the Production Area as part of this program. About 250 of these borings were completed during 1989, with the remainder to be completed during 1990. Each was less than six meters (20 ft) deep into the clay-rich soils overlying the regional sand and gravel aquifer. The purpose of these borings was to look for above-background concentrations of hazardous substances in the soil and perched water systems underlying the Production Area.

Based on the results of the continuing investigations in the Production Area, RI/FS personnel have identified isolated areas of above-background concentrations of uranium in perched water and soils. Groundwater beneath or in the vicinity of Plants 6, 9, and 2/3 contain elevated concentrations of uranium. While the elevated concentrations are limited to perched water systems and represent no near-term threat to onsite or offsite populations, the FMPC began extracting and treating the perched groundwater in 1989 at Plant 6. Additional investigations and/or removal actions will be carried out at Plants 9 and 2/3 during 1990.

During 1989, the FMPC used magnetic surveys, trenching and borings to investigate areas suspected of being contaminated. These investigations identified no significant releases or past disposal facilities. Activities in this program should be completed in 1990.

## *The Feasibility Study: Developing Solutions*

The FMPC Feasibility Study, which is also underway, will develop and evaluate alternatives for remediation. These evaluations will support the selection of a plan for final remediation at the site.

In an attempt to accelerate the RI/FS process and focus on high priority FMPC and community concerns, the Feasibility Study has been divided into five operable units. These operable units, identified below, include all currently identified areas of environmental concern at the FMPC. The feasibility study process for all five operable units continued during 1989.

- **Operable Unit 1**
  Waste Storage Area including the six waste pits.
- **Operable Unit 2**
  Solid Waste Units including the sanitary landfill, lime sludge ponds and fly ash piles.
- **Operable Unit 3**
  Facilities and Suspect Areas including FMPC Production area.
- **Operable Unit 4**
  Special Facilities including K-65 Silos and Silo 3.
- **Operable Unit 5**
  Environmental Media including regional groundwater and soils.

The final Feasibility Study reports will evaluate a number of remedial action alternatives and recommend preferred alternatives. The USEPA will invite public comment on the Feasibility Study reports and the recommended alternatives. After state and community comments are received and addressed, the USEPA will select the remediation methods for the FMPC and a Record of Decision will be written for each operable unit. Final Records of Decision for each of the operable units are expected to be issued by USEPA in mid-1991 through early 1992.

## *Remedial and Removal Actions*

As defined under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), a remedial action is a long-term solution to an environmental problem, whereas a removal action is an action to abate an immediate threat to health and the environment. A removal action is described in detail in the section

later in this chapter entitled "Complying with the National Environmental Policy Act."

Four removal actions have been specifically defined in the Consent Agreement recently negotiated with the USEPA. Other removal actions will be taken by the DOE in consultation with the USEPA as determined by Preliminary Assessments and Removal Site Evaluations to be conducted at suspect areas.

### Stabilizing the K-65 Silos

A consent agreement between DOE and USEPA requires the FMPC to investigate the implementation of near-term actions to stabilize the two K-65 waste storage silos located in the waste storage area. This work is being performed as part of Operable Unit 4 of the RI/FS.

The K-65 Silos are concrete storage structures containing radioactive radium-bearing residues from past DOE operations. The K-65 Silos contain approximately 8,800 metric tons (9,700 tons) of residues from the Manhattan Project, the World War II program that produced the first atomic weapons and other government operations. For this work, the United States imported a uranium-rich ore called pitchblende from the Belgian Congo. At the time the pitchblende was processed, the residue was not considered waste. The U.S. government had an agreement with the owner of the material to specifically precipitate, separate, and store the radium cake (the K-65). Following processing of the ore, the remaining materials were stored at the FMPC in two silos, known as the K-65 Silos. Since the uranium concentrations in this ore were so high, the ore also contained significant concentrations of radium, a natural decay product of uranium. The decay of the radium in these materials produces radon, a radioactive gas. The radioactivity levels of the residues are about the same as tailings from uranium mining and milling.

The consent agreement with USEPA requires the FMPC to address four specific items in connection with the K-65 Silos. These are:

- Provide temporary control to ensure the structural integrity of the K-65 Silos
- Provide temporary control over radioactive emissions
- Implement a radon and radon decay product monitoring program for the fence line and offsite environs

- Maintain an effective emergency response capability in the event of an unplanned release from the silos.

During 1989, the FMPC began a project to sample the contents of the K-65 Silos. A plan for final remediation of the material from the K-65 silos will be developed as part of the Feasibility Study for Operable Unit 4. Analytical results of representative samples of material from each silo will be used to evaluate applicable remediation technologies and to confirm existing information about the silos. The analysis will look at the radiological and chemical characteristics of the material as well as possible treatment methods.

The acquisition of representative samples of the material from silos 1 and 2 (the K-65 Silos) and silo 3 was attempted during the months of May, June, and July of 1989. The sampling was performed with a vibracore system consisting of an air-operated, vertically-vibrating head assembly. The vibrating sampling tube was lowered into each of four 46 cm (18 inch) diameter manways in the K-65 Silos and into three manways in silo 3. Silo 3 contains a dry, cold metal oxide material from which sufficient samples were acquired. The samples from silos 1 and 2 were not representative since only about 61 cm (2 feet) of material was acquired in each sample tube. The quantity of material retrieved, however, was sufficient to perform some analyses. Final results are expected by August 1990. An effort to acquire more representative samples from silos 1 and 2 will take place in July 1990 using a vibracore system that vibrates in three directions rather than one.

The final remediation actions for the K-65 Silos are being addressed as part of the sitewide RI/FS. The actions to be taken will be approved by the USEPA in the Record of Decision on Operable Unit 4 following completion of the RI/FS.

### Contaminated Water under FMPC Buildings

This removal action involves the pumping of contaminated water from beneath Plants 6, 9, and 2/3. A contaminated perched water zone was discovered in July 1988 during the excavation phase of a construction project inside Plant 6. A perched water zone is an area of water trapped in the upper till layer and is separated from the water table aquifer by a layer of impervious clay. (Till is a mixture of unstratified clay, sand, and gravel that was deposited by glaciers during the ice age. In the region of the FMPC the till lies over the sand and gravel aquifer.) Analysis of the water indicated above-

background levels of uranium and nitrates. The source of this contaminated water is believed to be a uranium-metal pickling process that uses nitric acid. This pickling process was carried out next to the excavation.

In an effort to eliminate the water, a 30 cm (12 inch) diameter hole was cut through the side wall of an adjacent concrete pit. In the concrete pit was a large holding tank that was no longer in use, plus piping and two sump pumps. The hole allowed the perched water to drain into the concrete pit. From there, it is being pumped into the Plant 6 water treatment system.

Perched water has continued to flow into the concrete pit at a rate of about 1,135 liters (300 gallons) per week. In response to this finding, a RI/FS Production and Additional Suspect Area Investigation plan was developed. The FMPC drilled 14 borings in Plant 6 to evaluate suspect areas; only three borings found perched water. Wells were installed in each of the borings where water was found. The water analyses from the borings indicated that the uranium concentration in the water was high enough to require a removal action. Pumping of the three wells began on November 6, 1989, and the water removed from the wells was treated in FMPC water treatment facilities. The Plant 6 Removal Action will continue until final remediation is implemented or until the affected water is removed. Pumping operations in Plants 9 and 2/3 are expected to begin in 1990.

**Waste Pit Area Stormwater Runoff Control**

Data from samples of stormwater runoff collected in the waste pit area have indicated that the concentration of uranium in the runoff is greater than allowed by DOE orders (the Derived Concentration Guides would be exceeded).[4] To prevent the runoff from entering Paddy's Run (along the western edge of the pits) the FMPC has begun developing a near-term solution as a removal action consistent with federal guidelines. The FMPC is performing an Engineering Evaluation/Cost Analysis (EE/CA) to select the preferred alternative from among these five included in the EE/CA:

- **Alternative 1**
  No action
- **Alternative 2**
  Surface capping of waste pits

- **Alternative 3**
  Surface capping with lateral drainage sump collection
- **Alternative 4**
  Collect and treat
- **Alternative 5**
  Source removal.

Preliminary drafts of the EE/CA have identified Alternative 4 as the preferred alternative.

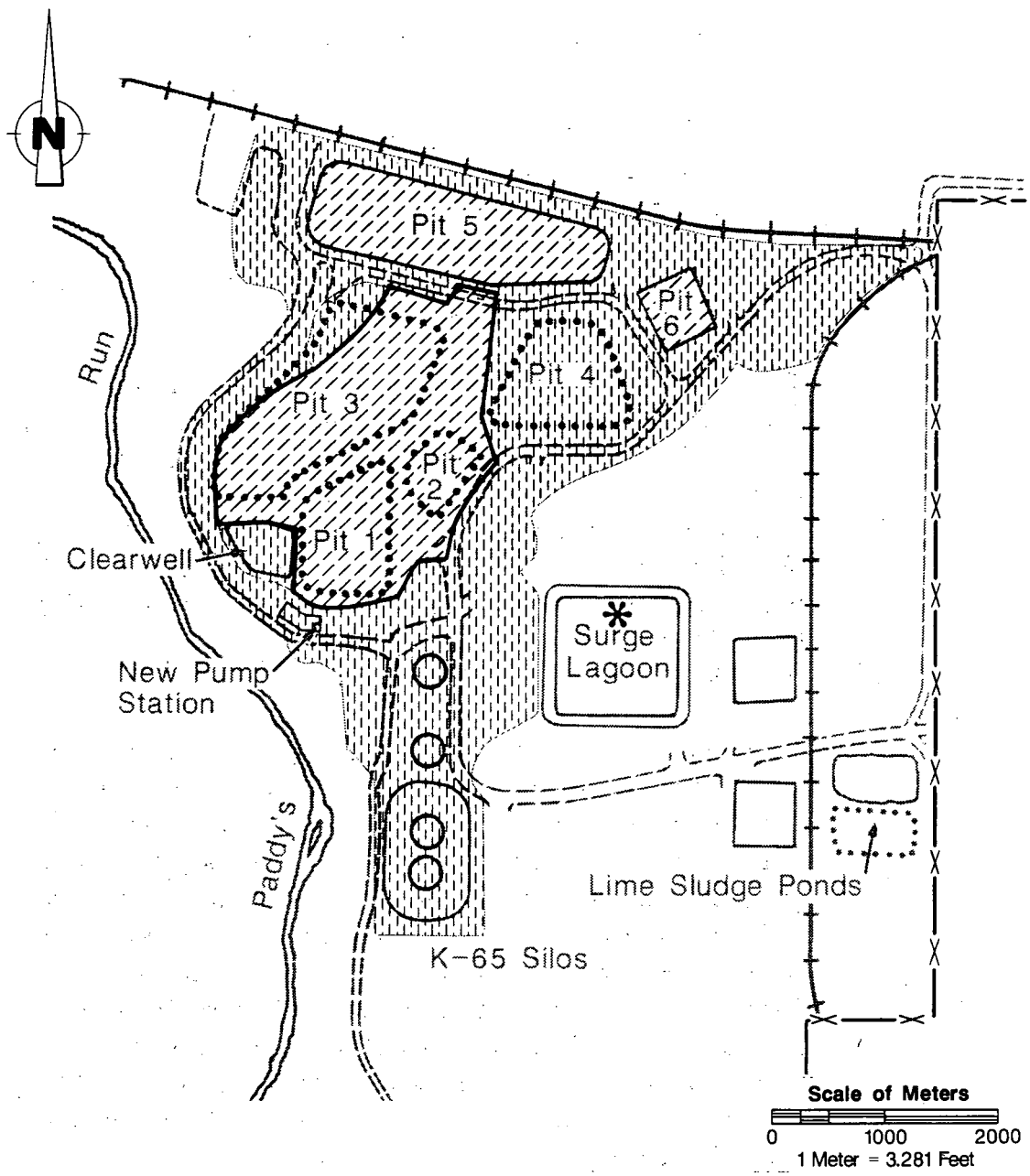
The project will focus on about 25 acres in the waste pit area plus the perimeter around the pits and silos (this includes the K-65 silos). This area is outlined in Figure 47. Presently, the stormwater that accumulates in pit 5 and a majority of runoff from the surface of pits 1, 2, and 3 collects in the clearwell before it is pumped to the biodenitrification surge lagoon. Stormwater that accumulates in pit 6 is pumped directly to the Biodenitrification Surge Lagoon (BSL). Figure 23 on page 61 shows the area of the waste pits that had controlled runoff during 1989.

In the collect and treat alternative, the FMPC will separate drainage areas within the waste pit area, thus isolating contaminated from noncontaminated runoff. Contaminated water not presently collected in the clearwell will be collected in a pumping station that will be located south of the clearwell. Drainage flow-control devices will be installed in existing upstream drainage channels located in the waste pit area to restrict peak flows to the new pumping station. The new system will pump the collected runoff to the BSL where suspended solids will settle before the water is treated in the biodenitrification towers and effluent water treatment system. After treatment, the water will be pumped to Manhole-175 and then into Great Miami River.

This project will greatly reduce contaminated runoff from the waste pit area to Paddy's Run, and this should be reflected in future data from surface water sampling in Paddy's Run.

### South Groundwater Contamination Plume

The uranium contamination plume south of the FMPC discussed in the above RI/FS Groundwater Monitoring section is being addressed by a two-phase removal action prior to the final Operable Unit 5 Record of Decision. The first phase will involve providing




## LEGEND

| | |
|---|---|
| This Area Will Drain to Clearwell | Production Area Perimeter |
| This Area Will Drain to New Pump Station | * All Shaded Areas Will be Pumped to Surge Lagoon |

Figure 47. Proposed Stormwater Runoff Control for Waste Pit Area

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alternative water supplies to two industrial users south of the FMPC. It is proposed that the second phase will entail drilling and pumping several wells to intercept the plume to slow or stop its migration southward. All groundwater monitoring and computer modeling for this removal action is an integral part of the RI/FS. The preparation of final design drawings for both phases will follow the approval in 1990 of an Engineering Evaluation/Cost Analysis (EE/CA) that was submitted for USEPA and public review in mid-April 1990.

### Other Removal Actions

Other removal actions may be identified and initiated as a result of RI/FS findings or to support other site activities. A removal action was initiated in the spring of 1989 to address uranium contamination of soil resulting from the overflow of effluent from the FMPC outfall line at Manhole-180.

Environmental Monitoring personnel collected three soil and corn samples next to the area that was contaminated by the Manhole-180 liquid effluent spill (Figure 48). The results from this sampling show that there was no statistically significant increase in uranium concentration in the three corn samples when the data are compared with a control group of nine corn samples taken during the same 1989 harvest season from farmland located between 1.4 km (0.87 miles) and 48 km (30 miles) from the center of the FMPC production area.[41] In fact, the highest uranium concentration in corn collected near Manhole-180 (0.0024 pCi/g) was only 53% of the average for the control group (0.0045 pCi/g) collected. (The produce and soil data are presented in Table 4).

**Manhole - 180 Corn & Soil Samples**

| Uranium Concentration (pCi/g) | |
|---|---|
| Corn | Soil |
| 0.0023 ± 0.0007 | 4.5 ± 1.4 |
| 0.0024 ± 0.0008 | 6.3 ± 1.9 |
| 0.00049 ± 0.00007 | 5.4 ± 1.7 |

This removal action included sampling to identify the extent of contamination, the removing and transporting contaminated soil, providing clean topsoil to replace removed soil, and collecting and analyzing samples to verify that all contaminated soil had been removed. Hundreds of samples were taken from the area near Manhole-180 (the grid area in Figure 48). The data were submitted to USEPA and are in the Administrative Record for the RI/FS.[42] Final release of the affected property for unrestricted use is expected in 1990.

## Managing Thorium at the FMPC

Since the early 1970s, the FMPC has served as the federal government's storage site for thorium, a naturally occurring radioactive element. Even prior to its designation as the federal repository, the FMPC studied possible uses for thorium, and had processed the material for use at other government facilities. All thorium processing at the FMPC ceased in 1979.

In 1988, there were about 1,100 metric tons (1,200 tons) of thorium stored in a silo, bins, steel drums and other containers on the plant site. About two-thirds of this material was processed onsite, with the remaining portion delivered from other DOE facilities.

The FMPC is carefully managing the thorium to reduce the potential radiation hazard to employees, local residents and the environment. For example, everyone entering thorium storage areas must obtain a radiation work permit which lists the specific safety requirements and additional guidelines that must be observed while in the area. The FMPC is taking steps to improve its thorium storage capabilities until a final decision is made by the government on the final storage location of the thorium materials.

### Current Thorium Storage Areas

The thorium stored at the FMPC consists of various materials, principally thorium oxides (generally a fine powder), processing residues in a variety of forms, and a small quantity of thorium metal. The Plant 8 silo and bins had contained about 175 metric tons (190 tons) of bulk thorium oxide materials, plus inert materials like diatomaceous earth. A small quantity of thorium nitrate solution (nine metric tons [9.9 tons]) is stored in Pilot Plant Tank 2. The majority of the remaining thorium, about 13,300 containers (containers vary in size from 55 gallon drums to drums as small as one gallon), is stored in warehouses (Buildings 64, 65, 67, and 68 in Figure 3).

### Improving Thorium Storage Areas

The FMPC has developed a comprehensive three-project plan for improving the temporary storage conditions for the thorium inventory. All of the thorium materials will be identified, inventoried, and repackaged or overpacked in the course of the project.

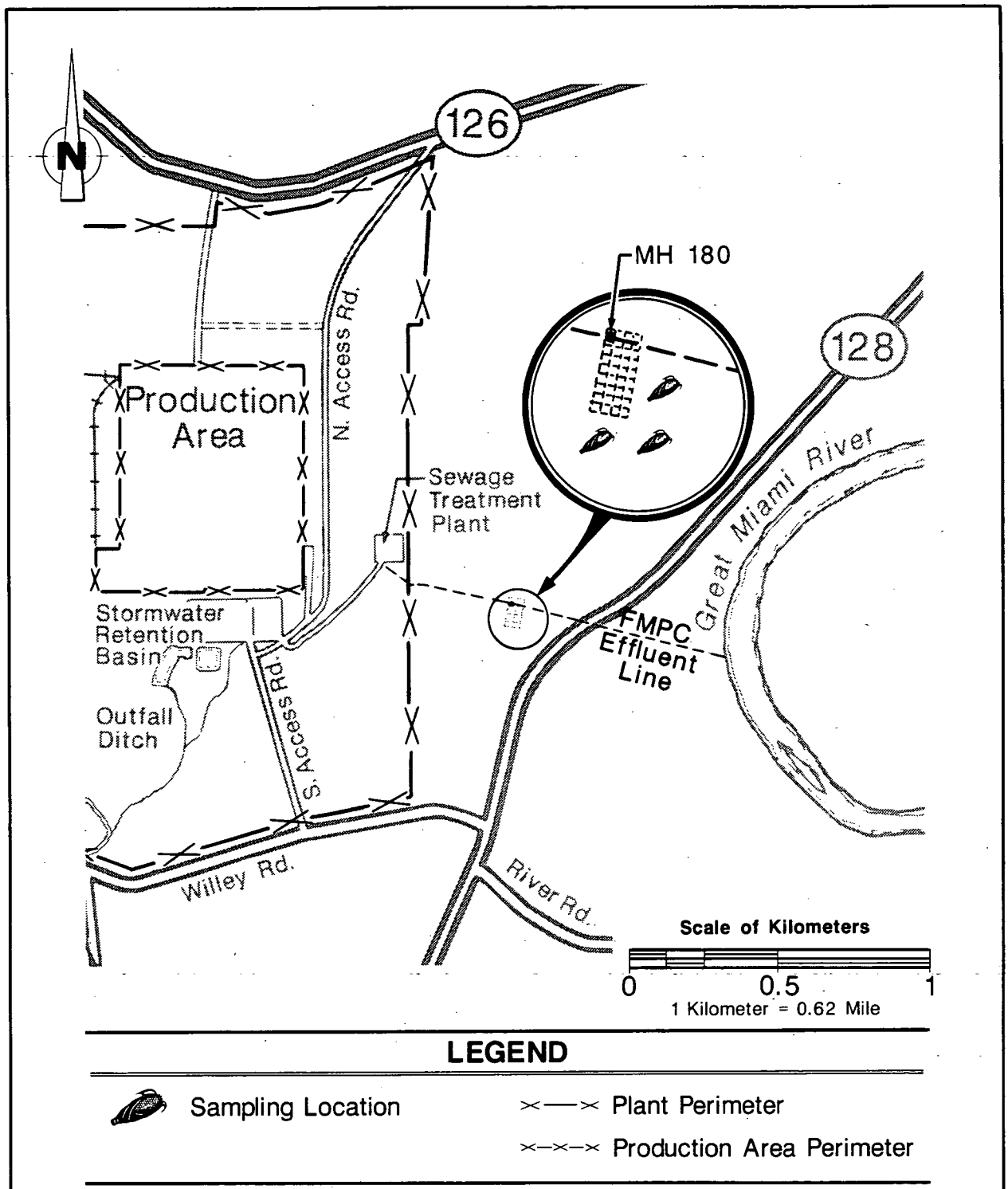


Figure 48. Corn Sampling near Manhole - 180

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The first project, completed in March 1989, addressed the bulk thorium materials in the Plant 8 silo and bins. As the bulk thorium was removed from the silo and bins, it was placed in double-containment drums called overpacks (a 48-gallon drum is packaged inside a 55-gallon drum), inventoried and monitored. The drums were then stored in an onsite warehouse located along the northern edge of the production area, away from daily plant operations. This thorium repackaging project was completed in March 1990. The silo and bins were then decontaminated and demolished.

The second project was the overpacking of the 241 containers (212 of the containers were drums) stored outdoors. A remote system to handle, identify, and overpack the 241 thorium drums and containers was designed. Each container was inventoried, weighed, and overpacked, then placed in temporary storage at the FMPC.

The third project, overpacking 13,000 drums of thorium stored in Buildings 64, 65, 67, and 68, will begin later in 1990.

By completing two of these projects, the FMPC has significantly reduced the potential for any accidental release of thorium through a structural failure or a deteriorating container. The new overpack containers will also protect the thorium materials from the weather and greatly reduce the possibility of any thorium being released to the environment. By removing the Plant 8 silo and bins and storing the thorium further away from daily operations, exposures from the thorium to employees working in the production area will be kept to a minimum.

# Water Compliance Activities

Several significant events and special studies were performed in 1989 to support water compliance activities, including:

- Best Management Practices Plan
- Status of water permits
- Water improvement projects.

## Best Management Practices Plan

The FMPC submitted a Best Management Practices (BMP) Plan to OEPA in February 1988 to protect the surface waters surrounding the FMPC from any significant release of toxic or hazardous substances. Some of the "best management practices" presented in the plan include:

- A hazardous-materials inventory
- A spill-risk assessment
- Spill reporting and record-keeping procedures
- Material-storage-and-compatibility requirements, good housekeeping practices, spill prevention, preventative maintenance and inspection, and security practices.

By observing these practices, FMPC employees can reduce the likelihood of a spill and will know how to respond quickly if a spill does occur.

To facilitate the implementation of the BMP plan, an action plan was prepared that includes such items as training in BMP procedures for appropriate employees, developing a site-spill response procedure, and stormwater runoff control practices. During 1989, the number of planned action items increased to 38 from 34. Twelve of the action items have been closed, and the remaining 26 items have been divided into 61 subtasks. Thirty three of the 61 subtasks had been completed by the end of 1989, and the remaining subtasks are scheduled to be completed during 1990.

## Status of Water Permits

During 1989, the FMPC submitted applications for two Permits to Install (PTIs) for planned wastewater treatment facilities: 1) Process Wastewater Biodenitrification and 2) Biodenitrification Effluent Treatment System. OEPA issued three PTIs — the two mentioned previously and, 3) Modification of the Plant 8 sump.

Furthermore, the OEPA issued a draft of the FMPC NPDES permit renewal for public comment on July 24, 1989. After the thirty-day public comment period, FMPC personnel continued to work closely with the OEPA to resolve remaining issues so that the permit could be issued. Requirements in the new permit will significantly

increase effluent monitoring and provide for increased control of discharges.

## Activities and Projects to Improve Compliance with Water Regulations

The following is an update on activities and projects which were part of the FMPC water compliance efforts during 1989:

- The Stormwater Retention Basin
- Modifying the Biodenitrification Surge Lagoon piping system
- Upgrading effluent sampling and monitoring capabilities
- Water plant residual pond
- Rebuilding onsite monitoring wells
- Improving ultraviolet disinfection
- The Coal Storage Facility.

### Operating the Stormwater Retention Basin

The Stormwater Retention Basin is designed to retain and settle the solids present in runoff from the FMPC process area, administration area and adjacent parking lots before it is discharged to the Great Miami River through Manhole-175. By capturing this runoff and controlling its discharge to the river, the SWRB greatly reduces uranium-bearing materials and other solids from these areas of the site from entering Paddy's Run.

The first SWRB began operating on October 26, 1986 and had a capacity of about 24 million liters (6.3 million gallons). This basin is capable of containing the runoff from 7.6 cm (3.0 in) of rain within 24 hours (a two-year, 24 hour storm). As part of the Consent Decree with the State of Ohio, the SWRB was expanded in 1988 to hold about 42 million liters (11 million gallons). This will contain the runoff from 10.4 cm (4.1 in) of rain (38.6 million liters or 10.2 million gallons). This amount of rain within 24 hours has a 10% chance of occurring in any one year. This is known as a 10-year, 24-hour storm event. The expanded SWRB began operating on December 28, 1988.

For 1989, over 257 million liters (68 million gallons) of water were pumped from the SWRB through Manhole-175. There were two overflows of the SWRB during the year, totaling about 2.3 million

liters (600,000 gallons). In late September, the west basin of the SWRB was drained and the sediments were stored in about 700 55-gallon drums. Analysis revealed that the material was not RCRA waste.

### Modifying the Biodenitrification Surge Lagoon Piping System

The Biodenitrification Surge Lagoon (BSL) was built to allow for even processing of nitrates over an extended period in the Biodenitrification Facility (BDN). The BSL, which has a capacity of about 30,600,000 liters (8.1 million gallons), controls the flowrate into the BDN (Facility 18D in Figure 3).

The BSL was built in the mid-1980s adjacent to two wastewater pipelines. Portions of these wastewater pipelines are located close to the BSL earthen berm. If one of these pipelines were to rupture during pumping operations, enough earth could wash away or the subsoil would be saturated causing a structural weakening of the berm. Then the berm wall could fail causing a substantial release of wastewater containing elevated levels of nitrates into Paddy's Run. This potential release would violate the Consent Decree established between DOE and the OEPA.

With this project, the FMPC proposes to modify portions of the two existing wastewater pipelines next to the BSL. The portion of these pipelines that run parallel to the berm will be relocated a safe distance from the lagoon. The portions of these pipelines used to direct wastewater into the lagoon will be routed above-ground so they can be inspected on a regular basis. This project reduces the likelihood of a large release of highly nitrated water.

### Upgrading Effluent Monitoring Capabilities

During 1989, the FMPC completed a project to upgrade the Manhole-175 instruments used to provide data for effluent flow, conductivity, suspended solids, dissolved oxygen, temperature, and pH. All effluent from the FMPC, including stormwater runoff stored in the Stormwater Retention Basin and process effluent is pumped to and passes through Manhole-175 before it is released to the Great Miami River.

Due to the age and the physical condition of the instruments, their accuracy is limited and it has been difficult to maintain them. The FMPC installed new sampling meters at the SWRB, SSLS, and

Manhole-175 to provide accurate data on flow, conductivity, suspended solids, temperature, and pH. In addition, dissolved oxygen is also monitored at Manhole-175. During June 1989, construction of new buildings was completed at Manhole-175 and the SWRB to house the new instrumentation.

These improvements in the sampling/monitoring program help the FMPC characterize surface water runoff and better protect the groundwater and surface water from pollutants.

**Water Plant Residuals Pond**

Since the early 1950s, raw water has been pumped from deep wells and treated to produce potable water for the FMPC. Naturally-occurring salts that interfere with the lathering of soap and general quality of water are removed from the well water. The resulting calcium and magnesium precipitates are removed and placed in an existing sludge bed located in the waste storage area. Here the heavier particles settle out of solution for disposal. The remaining clear water is then pumped from the sludge bed where it is treated before it is released through Manhole-175 to the Great Miami River.

The existing sludge bed has been virtually filled. Since drinkable water continues to be produced at the FMPC, some alternative sludge disposal techniques or location is needed. With this project, the FMPC proposes to build an additional storage facility for water-plant sludge. The pond is to be lined with a water-resistant clay that will help to protect the groundwater. The additional storage capacity (about 7.6 million liters or 2 million gallons) should be adequate for the next 10 years.

**Onsite Monitoring Wells Improvement Project**

Many of the onsite monitoring wells were installed between 1959 and 1965, and, due to their age, needed to be repaired. The outside casing of some wells had deteriorated due to weather, while other wells required new components. Of the 13 wells examined by a subcontractor, eight needed to be upgraded. New well seals, discharge tubing, electrical wiring, locking covers, and pumps were installed. Moreover, the ground around each well was graded and gravel added to help surface water drain away from the well. During this project, FMPC personnel were not able to sample the wells, and data for 1988 and part of 1989 were limited.

**Improving Disinfection Process at the FMPC Discharge to the Great Miami River**

As part of the treatment of sanitary waste at the FMPC's sewage treatment plant, ultraviolet light is used to kill harmful bacterial. This system worked adequately except when the unit had to be shut down for routine maintenance or repair. Then, chlorine was added to the water to kill the bacteria. In addition, when the biodenitrification tower came on-line, the concentration of total suspended solids in the effluent greatly increased. The UV light could not penetrate the solids and the bacteria were not killed. These conditions caused the FMPC to exceed the discharge limits for bacteria (fecal coliform) and residual chlorine at Manhole-175, the FMPC discharge to the Great Miami River.

To solve this problem, the FMPC began construction in September 1989 of a second ultraviolet unit to operate in parallel with the existing unit. In this way, maintenance can be performed on one of the UV units without interrupting the disinfection process. With a complete ultraviolet disinfection system, the chlorination operations will be discontinued, eliminating potential noncompliances for residual chlorine at Manhole-175. Furthermore, the biodenitrification operation has been adjusted to reduce the total suspended solids in the effluent pumped to the sewage treatment plant. The project is scheduled to begin in the latter part of 1990.

**The Coal Storage Facility**

To comply with the Consent Decree with the State of Ohio, the FMPC conducted a subsurface investigation of the coal storage facility and its runoff collection basin in July 1988. The purpose of this investigation was to determine the permeability of the soils underlying the area and to determine if any leaching of acidic runoff had occurred. The subsurface investigation included six soil borings, four under the coal storage area and two adjacent to the runoff collection basin. These borings were logged, sampled, classified, and analyzed for soil pH and permeability. Test results showed no evidence of acidic leaching, and indicated that the existing permeabilities satisfied the requirements set forth in the Consent Decree.

Based on these results, the OEPA has agreed that a liner will not be required beneath the coal storage area, and that a liner will not be required beneath the runoff collection basin provided that the FMPC

performs groundwater monitoring close to the basin. This approval was received in September 1989.

The FMPC has agreed to complete the installation of the monitoring equipment within 180 days of receipt of an approved PTI. The proposed monitoring equipment includes two groundwater monitoring wells, one on each side of the basin, and a level probe for the basin with an associated strip-chart recorder.

# Air Compliance Activities

The following is an update on activities which were part of the FMPC air compliance efforts during 1989:

- Federal Facility Compliance Agreement (FFCA) stack sampling
- Meteorological monitoring system
- Status of air permits
- Complying with NESHAP.

## *Stack Sampling and Testing*

On July 9, 1989, production-related activities at the FMPC were suspended. Since FFCA stack testing was scheduled for July and August 1989, testing was postponed and will be rescheduled if production resumes.

These tests are a way to compare the results of the sampling method commonly used at the FMPC (single point) with the isokinetic Method 5 test specified by USEPA. The Method 5 test consists of sampling effluent air discharged from the stacks for particulate content which, in turn, is analyzed for radionuclide content. The Method 5 test is considered to be a more representative and accurate way of estimating emissions.

## *Meteorological Monitoring System*

The FMPC installed an onsite meteorological monitoring system in August 1986. The system includes a meteorological tower,

monitoring instruments, a data logger, and a computer. The tower instruments measure wind speed and direction, ambient air temperature, lapse rate (a measure of atmospheric stability), dewpoint temperature, relative humidity, barometric pressure, sigma theta (the standard deviation of horizontal wind direction over time and also a measure of atmospheric stability), and precipitation.

Before the tower was installed, and at times when the onsite meteorological system was not operating, the FMPC obtained its meteorological data from the Greater Cincinnati International Airport. The onsite system enables the FMPC, and in particular the Emergency Operations Center, to use site-specific meteorological data, thus improving the accuracy of computer models used to estimate the doses from routine releases as well as doses from an accidental release at the FMPC. The data were also used in the AIRDOS-EPA computer codes to calculate the dose to the population as described in Chapter Four.

The meteorological monitoring system operated satisfactorily for 350 days during 1989. Lightning disrupted operation of the tower on two separate occasions: March 15 to March 20 and April 21 to May 2. Other instances of system downtime occurred during maintenance and calibration periods. The FMPC installed additional surge protection on the tower and associated equipment in May to help eliminate downtime from lightning strikes.

## Air Permit Applications

Under provisions of the Ohio Administrative Code and to comply with the Clean Air Act, the FMPC must apply for permits to install and to operate equipment that are sources of emissions to the atmosphere. During 1989, the FMPC submitted 13 PTIs and 22 PTOs applications to OEPA for their review and approval. The applications consist of responses to questions on emissions, process, and control equipment for each source to demonstrate that the FMPC complies with regulations.

## Complying with NESHAP

Several activities took place during 1989 related to FMPC compliance with National Emission Standards for Hazardous Air

Pollutants (NESHAP). Under the NESHAP Program, USEPA regulates FMPC radionuclide air emissions.

The FMPC and USEPA conducted negotiations in order to establish a Federal Facilities Compliance Agreement (FFCA) on FMPC compliance with NESHAP. When completed, the FFCA will clarify the NESHAP requirements for the FMPC.

Eight applications for Approval to Modify pursuant to NESHAP regulations were submitted to USEPA for FMPC radionuclide sources during 1989. All eight applications were promptly approved.

# Complying with the National Environmental Policy Act

The National Environmental Policy Act, signed into law on January 1, 1970, is the basic national charter for the protection of the environment. NEPA establishes environmental policy to prevent or eliminate damage to the environment and to enrich our understanding of ecological systems and natural resources. In addition, NEPA sets goals and provides means for carrying out the policy. On November 28, 1978, the President's Council of Environmental Quality (CEQ) issued guidelines to federal agencies on how to comply with NEPA policies and procedures and prepare their own procedures designed to supplement CEQ regulations. This review process is intended to help public officials make thoughtful decisions that are based in part on a clear understanding of the environmental consequences of a federal action.

At the earliest stage of a project's development, a facility such as the FMPC must screen federal environmental statutes and regulations to make sure that all environmental requirements are included in overall project planning. A series of questions relating to how a project may effect the environment help determine which federal, state, and local statutes and regulations apply to the proposed action. Specific steps to determine the impact of the proposed project on these resources are discussed as part of the NEPA documentation for the project. In addition, appropriate federal, state, and local agencies must be contacted very early in the planning stages to identify

environmental resources that could be affected by the proposed project. This process (known as the NEPA integration process) allows early identification and proper consideration of environmental issues, alternative actions, and mitigation measures before a project begins.

At the FMPC, projects are considered under one of four NEPA scenarios, and are discussed in the following sections:

- Renovation Actions that are included in the site-wide Renovation Environmental Impact Statement (EIS), and memo to file documents which are temporary or interim NEPA documents to be phased out by September 30, 1990. These are used to authorize personnel to proceed with renovation construction projects while the Renovation EIS is being prepared.
- Remedial Actions that are covered by Feasibility Studies/Environmental Impact Statement(s).
- Removal Actions which will be initiated before the RI/FS-EIS Record of Decision.
- Other actions or projects that do not fall into one of these three categories subject to categorical exclusions.

## Renovation Actions

The original intent of the FMPC EIS was to include both Renovation and Remedial Actions. Renovation is defined in the sitewide EIS as "changes to existing facilities and the construction and operation of new and replacement facilities/systems." These changes are designed to improve environmental, safety and health conditions and plant reliability; to maintain production capacity for future national defense needs; and to enhance management of hazardous and radioactive waste materials. There were 326 renovation and remedial projects included in the original scope of the EIS. During 1987-1988, as work continued on the EIS, DOE decided that the EIS would focus on renovation projects and remedial actions would be discussed as part of the RI/FS process. In order for projects to proceed while the Renovation EIS was being prepared, separate interim NEPA documents have been written for more than 270 renovation projects in the EIS.

## Remedial Actions

During the same time-frame that decisions were being made concerning the FMPC's EIS, the DOE and USEPA signed a Federal Facility Compliance Agreement in July 1986. DOE agreed to conduct an RI/FS, and a workplan was approved in May 1988 by USEPA. Consequently, a major concern facing FMPC has been how to comply with NEPA and CERCLA and the respective documents, the EIS and RI/FS, without delaying either process. In August 1988, DOE issued a policy intended to integrate the requirements of NEPA with the planning and environmental review procedures of the CERCLA RI/FS process so that all such procedures run concurrently rather than consecutively. This policy applies only to remedial actions under CERCLA, not removal actions. The primary means for integrating NEPA and the RI/FS process for remedial actions under CERCLA is the RI/FS process, supplemented to meet NEPA requirements. The final NEPA/CERCLA Integration Plan, submitted to DOE/HQ in January 1990, discusses the approach to integrating the requirements of NEPA with the operable unit concept of CERCLA.

## Removal Actions

Removal Actions are defined either as nontime-critical or time-critical based upon the urgency of the actions to be taken. A nontime-critical removal action is a project which the DOE, as lead agency, determines has a planning period of at least six months before onsite activities begin. The FMPC prepares an engineering analysis known as an Engineering Evaluation/Cost Analysis (EE/CA). In an EE/CA, the FMPC analyzes the problem and develops possible solutions. After considering the options, the FMPC selects a removal action alternative. EE/CAs are available for public review and are submitted to DOE/HQ and USEPA for review and approval.

If DOE determines there is a threat to public health, welfare, or the environment which will take less than six months for onsite cleanup activities to begin, it may begin a time-critical removal action. These actions are designed to prevent, minimize, stabilize, or eliminate the release or threat of release. Appropriate documentation, which includes the EE/CAs and a NEPA assessment, is prepared for the removal actions and for the Administrative Record.

### Other Actions

Any action that does not fall into one of the aforementioned NEPA categories must still be addressed for NEPA compliance.

All federal agencies are subject to NEPA, and all must abide by the President's Council on Environmental Quality regulations. These regulations provide the direction for incorporating environmental review in the planning and execution of federal actions and set forth procedures for establishing legal documentation of such review. NEPA documents prepared during 1989 included 20 Categorical Exclusions, 20 NEPA Fact Sheets, two Engineering Evaluation/ Cost Assessments, and two Notations to File.

## Estimating Emissions from Unmonitored Stacks

During the 1988 review of sources at the FMPC, it was noted that several sources onsite were not routinely sampled for emissions. In order to reasonably quantify emissions of radionuclides from these sources engineering estimates were developed based upon key activities in the operation that produce the emission (for example, number of batches, concentration of radionuclides in solution). Many of the emission models are based upon data obtained from sampling. The estimates are used since permanent sampling is not feasible nor available for these operations. The estimating techniques developed for unmonitored stacks in 1988 were used to estimate emissions during 1989.

## Reducing Chemical Inventories

With the changing mission of the site, many of the chemicals associated with production operations were targeted for removal from the site, including the following:

- Uranium hexafluoride
- Magnesium

- Anhydrous Ammonia
- Miscellaneous Chemicals.

Since the facility that processed uranium hexafluoride ($UF_6$) was shut down, the $UF_6$ inventory, stored in large steel cylinders at the site, was no longer required.

Most of the $UF_6$ was shipped from the site during 1989. An additional group of small cylinders containing about 45.4 kg (100 pounds) of $UF_6$ remain onsite requiring reapportionment of the amount of $UF_6$ within them. This material transfer was planned for February 1990, after which these cylinders will also be removed from the site. At this time, essentially no production-scale quantities of $UF_6$ remain onsite. A net reduction in potential chemical hazards at the site is seen as a primary benefit from this inventory removal.

Magnesium inventories were reduced during 1989 through a sale of overstock to the private sector. A magnesium grade for use in production of high iron content uranium metal was targeted for sale since the government programs requiring this metal grade were discontinued. Nearly 80,000 kg (176,000 pounds) of ground magnesium were removed from site, further reducing potential chemical hazards at the site.

Additional magnesium stored onsite as contingency for programs not yet discontinued, will be removed once programs requiring high purity uranium metal no longer rely on the FMPC.

Production programs requiring anhydrous ammonia were suspended during 1989. As a result, 14,778 kg (32,580 pounds) of anhydrous ammonia were sold to a private distributor thereby reducing the potential chemical hazard onsite.

Miscellaneous nonradiological laboratory chemicals no longer used in the laboratory were collected during the calendar year for one-time disposition based upon the type of chemical and disposal methods required by regulations.

# Unusual Events

During 1989, the FMPC modeled two events for the AIRDOS-EPA calculations to estimate offsite impacts even though they were considered to contribute little if anything to the offsite dose. These two events were chosen by FMPC personnel after a thorough review of the Assistant Duty Officers Daily Log in the Emergency Operations Center, 163 Minor Event Reports, 27 Unusual Occurrence Reports, and the daily log of spills compiled by the Manager of Utilities. Events that had possible offsite implications were investigated, and all but the two discussed in the following paragraphs were not included in AIRDOS-EPA.

## *Uranium-Fines Fire Near Plant 6*

A uranium-fines fire occurred on the southeast storage pad of Plant 6 on June 1, 1989. The pad is open and has an easterly exposure. Wind speed at the 10 meter height (33 feet) was 13 kph (8.1 mph). The fire lasted about one-half hour and caused little damage and no injuries were reported.

Seventy-seven kilograms (169 pounds) of very small chips of uranium metal, called fines, were collected in a 30-gallon drum as specified in FMPC procedures. Next, the drum was overpacked in a 55-gallon container, placed under a sprinkler head, and dry ice was placed on top of the fines. An employee noticed smoke coming from the drum and sounded the alarm. An FMPC emergency response team quickly extinguished the fire. As a precaution, one employee who initially responded to control the fire was sent for urinalysis to check for uranium intake. For modeling purposes, the fire resulted in an estimated loss of 0.38 kg (0.84 pounds) of uranium to the environment.[43]

## *Emission from a Spill of Solid Material Near Plant 7*

The second unusual event was a spill of solid material. The gravel area south of Plant 7 is routinely used as a parking area. Sometime in the spring of 1989, a black material (thought to be fly ash) fell from a dump truck. In July 1989, the material (615 kg/1,356 pounds) was placed into three drums, and a sample was sent for analysis. The data indicated a uranium concentration of 1.0%. The potential release was estimated to be 0.002 kg (0.004 pounds).[44]

# APPENDICES


**A** FMPC Environmental Monitoring Data for 1989

**B** 1987-1989 Monitoring Data Presented as Bar Graphs

**C** Chemical Release Information for 1989

**D** References

**E** Glossary of Terms

**F** Environmental Monitoring Report Distribution List

APPENDIX A

# FMPC Environmental Monitoring Data for 1989

The FMPC designed and conducted numerous sampling and analysis procedures to evaluate compliance with environmental regulations and to obtain accurate indications of the effects of the facility's operations on the environment during 1989. The sampling and analysis results are provided in summary tables.

## TABLE 1
## PARTICULATES, URANIUM, AND GROSS BETA CONCENTRATIONS IN AIR, 1989

| Sampling Location[a] | Particulates[b1] µg/m³ | | | | | Uranium[b2] µCi/ml x $10^{-15}$ | | | | | Gross Beta[b3] µCi/ml x $10^{-15}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Samples | Minimum | Maximum | 1989 AVG. | 1988 AVG. | Number of Samples | Minimum | Maximum | 1989 AVG. | 1988 AVG. | Number of Samples | Minimum | Maximum | 1989 AVG. | 1988 AVG. |
| AMS 1 | 52 | 16.2 | 70.8 | 31.7 | 31.6 | 52 | 0.00 | 1.07 | 0.31 | 2.60 | 52 | 8.89 | 51.4 | 22.0 | 24.2 |
| AMS 2 | 52 | 15.7 | 57.5 | 34.7 | 38.2 | 52 | 0.00 | 1.69 | 0.38 | 2.57 | 52 | 9.54 | 76.2 | 24.8 | 27.3 |
| AMS 3 | 51 | 16.5 | 82.1 | 35.8 | 35.7 | 51 | 0.00 | 2.66 | 0.71 | 3.59 | 51 | 11.98 | 65.8 | 26.5 | 28.8 |
| AMS 4 | 52 | 18.4 | 79.2 | 39.6 | 39.4 | 52 | 0.00 | 0.65 | 0.20 | 0.77 | 52 | 9.74 | 62.5 | 24.8 | 27.4 |
| AMS 5 | 52 | 14.3 | 73.3 | 34.6 | 36.6 | 52 | 0.00 | 0.80 | 0.22 | 0.83 | 52 | 10.06 | 81.6 | 26.6 | 32.9 |
| AMS 6 | 51 | 11.4 | 106.4 | 36.1 | 36.6 | 51 | 0.00 | 1.38 | 0.31 | 0.90 | 51 | 6.25 | 76.3 | 26.0 | 30.2 |
| AMS 7 | 52 | 19.7 | 84.6 | 37.8 | 37.3 | 52 | 0.00 | 0.70 | 0.17 | 0.50 | 52 | 10.24 | 101.0 | 30.8 | 34.2 |
| AMS 8 | 52 | 6.3 | 65.7 | 31.7 | 39.8 | 52 | 0.00 | 2.61 | 0.72 | 4.32 | 52 | 3.25 | 60.5 | 21.5 | 27.5 |
| AMS 9 | 52 | 16.3 | 86.8 | 37.4 | 40.8 | 52 | 0.00 | 6.62 | 1.84 | 6.78 | 52 | 8.74 | 56.7 | 24.0 | 28.9 |
| AMS 10 | 52 | 22.6 | 209.2 | 51.1 | 51.0 | 52 | 0.00 | 1.37 | 0.13 | 0.25 | 52 | 5.00 | 80.8 | 23.3 | 21.4 |
| AMS 11 | 52 | 18.1 | 67.6 | 37.1 | 40.9 | 52 | 0.00 | 0.19 | 0.07 | 0.29 | 52 | 11.28 | 40.7 | 20.7 | 23.7 |
| AMS 12 | 51 | 15.8 | 72.0 | 37.4 | 37.8 | 52 | 0.00 | 0.25 | 0.06 | 0.14 | 51 | 11.89 | 145.0 | 25.8 | 22.6 |
| AMS 13 | 52 | 19.9 | 113.7 | 45.4 | 48.7 | 52 | 0.00 | 0.28 | 0.09 | 0.63 | 52 | 4.37 | 50.3 | 21.3 | 28.4 |
| AMS 14 | 50 | 23.3 | 103.3 | 42.8 | 37.1 | 48 | 0.00 | 0.23 | 0.07 | 0.18 | 49 | 7.01 | 44.5 | 20.6 | 23.3 |
| AMS 15 | 15 | 10.8 | 86.6 | 44.6 | ... [c] | 15 | 0.00 | 0.18 | 0.08 | ... [c] | 15 | 11.44 | 37.1 | 21.3 | ... [c] |
| AMS 16 | 16 | 24.4 | 60.1 | 39.0 | ... [c] | 15 | 0.00 | 0.53 | 0.12 | ... [c] | 15 | 12.70 | 38.3 | 22.2 | ... [c] |

a. See Figure 9.
b. The following guidelines were used for comparison:
   1. Particulates = 50 µg/m³ (annual arithmetic mean) as stated in 40 CFR Part 50, National Ambient Air Quality Standards, July 1, 1988.
   2. Uranium = 100 x $10^{-15}$ µCi/ml as stated in DOE Draft Order. 5400.xx, March 18, 1988.
   3. Gross Beta = 100,000 x $10^{-15}$ µCi/ml as stated in 10 CFR Part 20, Appendix B.
c. Did not operate during 1988.

# TABLE 2
# RADIONUCLIDES IN AIR, 1989
(page 1 of 3)

| Radionuclide | Derived Concentration Guides[d] $\mu Ci/m^3 \times 10^{-6}$ | Concentration of Airborne Radionuclides at Air Monitoring Stations[a,b,c] in $\mu Ci/m^3 \times 10^{-12}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | AMS 1 | AMS 2 | AMS 3 | AMS 4 | AMS 5 | AMS 6 |
| Sr-90 | 9 | 12 ± 6.2 | 33 ± 7.8 | NA[e] | 24 ± 6.3 | NA[e] | 52 ± 9.5 |
| Tc-99 | 2000 | < 180 | < 120 | 160 ± 110 | < 160 | < 160 | < 160 |
| Ru-106[f] | 30 | < 11000 | < 9500 | < 11000 | < 9700 | < 9400 | < 9500 |
| Cs-137 | 400 | < 100 | < 94 | < 110 | < 97 | < 94 | < 95 |
| Ra-226 | 1 | 9.8 ± 1.9 | 15 ± 2.9 | < 0.53 | 1.0 ± 0.23 | 8.0 ± 1.7 | 16 ± 3.1 |
| Ra-228 | 3 | < 10 | < 9.4 | < 11 | < 9.7 | < 9.4 | 9.5 ± 4.0 |
| Th-228 | 0.04 | < 7.3 | < 8.0 | < 11 | < 9.7 | 8.3 ± 6.0 | 11 ± 7.5 |
| Th-230 | 0.04 | 8.8 ± 5.8 | 10 ± 6.5 | < 11 | < 9.7 | < 8.0 | < 9.5 |
| Th-232 | 0.007 | < 7.3 | < 8.0 | < 11 | < 9.7 | < 8.0 | < 9.5 |
| Np-237 | 0.02 | NA[e] | NA[e] | NA[e] | NA[e] | NA[e] | NA[e] |
| Pu-238 | 0.03 | < 2.1 | < 2.0 | 3.0 ± 2.1 | < 2.5 | < 2.7 | < 2.6 |
| Pu-239 | 0.02 | 0.22 ± 0.0023 | 0.23 ± 0.0023 | 0.49 ± 0.0033 | 0.20 ± 0.0021 | 0.20 ± 0.0020 | 0.20 ± 0.0018 |
| Pu-240 | 0.02 | 0.064 ± 0.00083 | 0.065 ± 0.00086 | 0.13 ± 0.0012 | 0.060 ± 0.00077 | 0.057 ± 0.00064 | 0.060 ± 0.00065 |
| Pu-241 | 1 | 0.85 ± 0.048 | 0.90 ± 0.044 | 2.0 ± 0.055 | 0.77 ± 0.055 | 0.69 ± 0.024 | 0.68 ± 0.034 |
| Pu-242[b] | 0.02 | 37 ± 2.1 | 37 ± 1.9 | 71 ± 2.1 | 32 ± 1.9 | 37 ± 1.5 | 48 ± 1.5 |
| U-234 | 0.09 | 86 ± 31 | 110 ± 37 | 200 ± 72 | 76 ± 27 | 43 ± 15 | 120 ± 41 |
| U-235 | 0.1 | 6.0 ± 0.17 | 7.3 ± 0.21 | 13 ± 0.38 | 4.0 ± 0.11 | 4.5 ± 0.13 | 6.0 ± 0.17 |
| U-236 | 0.1 | 2.4 ± 0.36 | 3.6 ± 0.55 | 8.4 ± 1.3 | 1.6 ± 0.24 | 1.8 ± 0.27 | 2.7 ± 0.41 |
| U-238 | 0.1 | 150 ± 0.03 | 190 ± 0.04 | 360 ± 0.07 | 100 ± 0.02 | 110 ± 0.02 | 160 ± 0.03 |

# TABLE 2
## RADIONUCLIDES IN AIR, 1989
(page 2 of 3)

| Radionuclide | Derived Concentration Guides[d] $\mu Ci/m^3 \times 10^{-6}$ | Concentration of Airborne Radionuclides at Air Monitoring Stations[a,b,c] in $\mu Ci/m^3 \times 10^{-12}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | AMS 7 | AMS 8 | AMS 9 | AMS 10 | AMS 11 | AMS 12 |
| Sr-90 | 9 | 7.7 ± 6.0 | 36 ± 7.2 | 18 ± 7.9 | 8.5 ± 3.1 | 7.1 ± 2.9 | 57 ± 6.9 |
| Tc-99 | 2000 | 170 ± 99 | < 160 | 330 ± 120 | < 2.4 | < 1.9 | < 2.1 |
| Ru-106[f] | 30 | < 10000 | < 9200 | < 10000 | < 1600 | < 1400 | < 1600 |
| Cs-137 | 400 | < 100 | < 92 | < 100 | < 180 | < 160 | < 170 |
| Ra-226 | 1 | 20 ± 3.6 | < 0.46 | < 0.52 | 55 ± 9.0 | 39 ± 6.6 | 39 ± 6.6 |
| Ra-228 | 3 | 13 ± 4.5 | < 9.2 | < 10 | < 20 | < 24 | < 13 |
| Th-228 | 0.04 | < 7.6 | < 19 | < 13 | 13 ± 4.0 | 4.0 ± 1.4 | 12 ± 3.4 |
| Th-230 | 0.04 | < 7.6 | < 19 | < 13 | < 2.2 | 2.6 ± 1.2 | < 1.7 |
| Th-232 | 0.007 | < 7.6 | < 19 | < 13 | < 2.2 | < 1.2 | < 1.7 |
| Np-237 | 0.02 | NA[e] | NA[e] | NA[e] | 0.22 ± 0.16 | < 0.21 | < 0.21 |
| Pu-238 | 0.03 | 5.5 ± 2.6 | < 7.8 | < 3.2 | < 0.17 | < 0.25 | < 0.19 |
| Pu-239 | 0.02 | 0.14 ± 0.0016 | 0.40 ± 0.0029 | 1.4 ± 0.013 | | | |
| Pu-240 | 0.02 | 0.044 ± 0.00046 | 0.11 ± 0.0010 | 0.23 ± 0.0024 | | | |
| Pu-239/240 | | | | | < 0.16 | < 0.24 | < 0.17 |
| Pu-241 | 1 | 0.39 ± 0.021 | 1.6 ± 0.033 | 3.5 ± 0.054 | | | |
| Pu-242[b] | 0.02 | 30 ± 1.4 | 81 ± 1.6 | 200 ± 4.1 | | | |
| U-234 | 0.09 | 77 ± 27 | 69 ± 25 | 530 ± 190 | 37 ± 13 | 20 ± 6.9 | 16 ± 5.7 |
| U-235 | 0.1 | 3.3 ± 0.09 | 13 ± 0.38 | 35 ± 1.0 | 2.4 ± 0.07 | 1.3 ± 0.04 | 1.1 ± 0.03 |
| U-236 | 0.1 | 1.3 ± 0.19 | 6.4 ± 0.98 | 20 ± 3.0 | 1.1 ± 0.17 | 0.60 ± 0.09 | 0.49 ± 0.07 |
| U-238 | 0.1 | 83 ± 0.02 | 370 ± 0.07 | 940 ± 0.18 | 63 ± 0.01 | 34 ± 0.01 | 28 ± 0.01 |

# TABLE 2
# RADIONUCLIDES IN AIR, 1989
(page 3 of 3)

Concentration of Airborne Radionuclides at Air Monitoring Stations[a,b,c] in $\mu Ci/m^3 \times 10^{-12}$

| Radionuclide | Derived Concentration Guides[d] $\mu Ci/m^3 \times 10^{-6}$ | AMS 13 | AMS 14 | AMS 15 | AMS 16 |
|---|---|---|---|---|---|
| Sr-90 | 9 | 11 ± 2.9 | 22 ± 12 | 20 ± 9.6 | 34 ± 8.9 |
| Tc-99 | 2000 | < 1.9 | < 1.9 | < 6.8 | NA[e] |
| Ru-106[f] | 30 | < 1400 | < 1500 | < 5100 | < 4700 |
| Cs-137 | 400 | < 160 | < 170 | < 560 | < 520 |
| Ra-226 | 1 | 14 ± 3.0 | 34 ± 5.9 | 84 ± 15 | 80 ± 15 |
| Ra-228 | 3 | < 16 | < 9.9 | < 50 | < 41 |
| Th-228 | 0.04 | 7.8 ± 2.8 | 11 ± 4.4 | 12 ± 5.4 | < 9.4 |
| Th-230 | 0.04 | < 1.9 | < 3.2 | < 5.2 | < 9.4 |
| Th-232 | 0.007 | < 1.9 | < 3.2 | < 5.2 | < 9.4 |
| Np-237 | 0.02 | 0.14 ± 0.085 | 0.14 ± 0.091 | < 0.62 | 0.64 ± 0.43 |
| Pu-238 | 0.03 | < 0.14 | < 0.14 | < 0.48 | < 0.46 |
| Pu-239/240 | | < 0.13 | < 0.13 | < 0.44 | < 0.43 |
| U-234 | 0.09 | 26 ± 9.3 | 21 ± 7.6 | 23 ± 8.1 | 30 ± 11 |
| U-235 | 0.1 | 1.7 ± 0.05 | 1.4 ± 0.04 | 1.5 ± 0.04 | 2.0 ± 0.06 |
| U-236 | 0.1 | 0.81 ± 0.12 | 0.66 ± 0.10 | 0.70 ± 0.11 | 0.92 ± 0.14 |
| U-238 | 0.1 | 45 ± 0.01 | 37 ± 0.01 | 39 ± 0.01 | 52 ± 0.01 |

a. See Figure 9.
b. Reported in units of $\mu Ci/m^3 \times 10^{-12}$ of air; the plus/minus values are the uncertainty in the analytical results at the 95% confidence level. (Pu-242 data reported in units of $\mu Ci/m^3 \times 10^{-18}$).
c. A composite of 50 weekly samples at AMS 14; 51 weekly samples at AMS 3 and AMS 6; 15 weekly samples at AMS 15; 16 weekly samples at AMS 16; 52 weekly samples at all other air monitoring stations.
d. Derived concentration guides from DOE Draft Order 5400.xx, 3-18-88. Continuous inhalation of this concentration will result in an effective dose equivalent of 100 mrem/yr (1 mSv/yr).
e. Not analyzed.
f. Composite sample activity adjusted to midpoint of sampling.

## TABLE 3
## URANIUM IN SOIL AND GRASS AND FLUORIDE IN GRASS, 1989

| Sampling Location[c] | Distance in km from center of FMPC | Soil[a] Total Uranium pCi/g dry[d,e] 0-5 cm | Soil[a] Total Uranium pCi/g dry[d,e] 5-10 cm | Grass[b] Total Uranium pCi/g dry[d,e] | Grass[b] Fluoride (ppm)[f] |
|---|---|---|---|---|---|
| **Onsite** | | | | | |
| AMS 9 | 0.10 | 15 ± 3 | 8.3 ± 1.6 | 2.9 ± 0.5 | 15 |
| AMS 8 | 0.15 | 23 ± 5 | 23 ± 5 | 0.25 ± 0.04 | < 1.8 |
| AMS 1 | 0.16 | 6.7 ± 2.1 | 6.5 ± 1.9 | 0.26 ± 0.05 | < 1.9 |
| AMS 3 | 0.16 | 79 ± 13 | 58 ± 9 | 1.0 ± 0.2 | < 1.8 |
| AMS 4 | 0.49 | 12 ± 3 | 10 ± 3 | 0.05 ± 0.006 | < 1.9 |
| AMS 6 | 0.63 | 8.7 ± 1.8 | 9.2 ± 2.4 | 0.26 ± 0.05 | < 2.0 |
| AMS 5 | 0.64 | 5.9 ± 1.7 | 6.8 ± 1.7 | 0.16 ± 0.02 | < 1.8 |
| AMS 2 | 1.1 | 16 ± 3 | 13 ± 2 | 0.12 ± 0.01 | < 1.9 |
| AMS 7 | 1.3 | 3.1 ± 1.1 | 4.8 ± 1.9 | < 0.01 NA[g] | < 1.9 |
| **Offsite** | | | | | |
| 30 | 1.3 | 15 ± 4 | 10 ± 2 | 0.05 ± 0.006 | < 1.9 |
| 31 | 1.9 | 7.9 ± 1.9 | 11 ± 3 | 0.07 ± 0.007 | 2.9 |
| 15 | 1.9 | 2.2 ± 1.0 | 2.4 ± 0.9 | 0.03 ± 0.003 | < 2.0 |
| 12 | 2.2 | 8.9 ± 2.6 | 6.3 ± 2.2 | 0.04 ± 0.005 | < 2.0 |
| 24 | 2.4 | 7.2 ± 2.2 | 9.1 ± 2.7 | 0.04 ± 0.003 | < 1.9 |
| 10 | 2.6 | 3.2 ± 1.1 | 2.8 ± 1.2 | 0.08 ± 0.010 | 3.4 |
| 25 | 2.7 | 7.4 ± 2.4 | 3.8 ± 1.4 | 0.02 ± 0.003 | < 1.8 |
| 11 | 3.7 | 5.9 ± 2.0 | 8.5 ± 2.7 | 0.06 ± 0.007 | 4.5 |
| 17 | 3.7 | 6.8 ± 2.5 | 4.2 ± 1.9 | 0.03 ± 0.003 | < 2.0 |
| 20 | 3.7 | 2.4 ± 1.0 | 2.6 ± 1.0 | 0.01 ± 0.002 | < 1.7 |
| 21 | 3.9 | 3.3 ± 1.3 | 2.9 ± 1.2 | 0.02 ± 0.003 | 4.2 |
| 13 | 4.2 | 6.5 ± 2.0 | 6.0 ± 1.9 | 0.01 ± 0.001 | 7.5 |
| 33 | 4.2 | 2.4 ± 1.0 | 2.9 ± 0.8 | 0.04 ± 0.004 | 12 |
| 23 | 4.3 | 3.8 ± 1.3 | 2.7 ± 1.2 | 0.02 ± 0.003 | 3.0 |
| 32 | 4.3 | 7.4 ± 2.4 | 2.9 ± 1.1 | 0.01 ± 0.001 | 5.0 |
| 22 | 5.0 | 3.6 ± 1.2 | 3.9 ± 1.3 | 0.01 ± 0.001 | 4.3 |
| 18 | 5.1 | 5.6 ± 2.2 | 5.8 ± 2.2 | 0.02 ± 0.002 | 2.8 |
| 14 | 5.4 | 2.7 ± 1.0 | 2.9 ± 1.1 | 0.02 ± 0.003 | < 2.0 |
| 19 | 8.8 | 3.8 ± 1.7 | 7.4 ± 2.4 | 0.03 ± 0.004 | 4.2 |
| 29 | 24 | 8.0 ± 2.7 | 2.8 ± 1.1 | 0.01 ± 0.001 | < 2.0 |
| 28 | 40 | 2.8 ± 1.2 | 1.9 ± 0.8 | 0.01 ± 0.001 | < 2.0 |

a. Soil samples taken at depth intervals of 0-5 cm and 5-10 cm.
b. Plant material primarily bromegrass (Bromus sp.), but other genera represented: Allium, Daucus, Hordeum, Medicago, Melilotus, Poa, Secale and Triticum.
c. Locations (see Figure 18) are listed in order of increasing distance from the center of the FMPC production area (Plant 4).
d. To obtain Bq/g, multiply pCi/g by 0.037.
e. The plus/minus values are the uncertainty in the analytical results at the 95% confidence level.
f. Contract laboratory did not report analytical uncertainty.
g. Not applicable.

## TABLE 4
## URANIUM CONCENTRATION IN SOIL AND PRODUCE, 1989[a]

Concentration in pCi/g dry weight[b]

| Location[c] | Distance from Center of FMPC (km) | Soil Concentration[d] |
|---|---|---|
| 2 | 1.3 | 5.9 ±1.8 |
| 9 | 1.4 | 4.0 ±1.3 |
| 10 | 1.6 | 2.0 ±0.8 |
| 13 | 1.6 | 2.5 ±0.9 |
| 1 | 1.6 | 3.6 ±1.4 |
| 3 | 1.8 | 5.1 ±1.5 |
| 8 | 1.9 | 3.1 ±1.0 |
| 6 | 2.0 | 2.8 ±1.1 |
| 5 | 2.1 | Not Sampled |
| 11 | 2.2 | 2.7 ±1.0 |
| 7 | 2.4 | 1.4 ±0.8 |
| 12 | 2.9 | 1.7 ±1.1 |
| 4 | 3.2 | 3.3 ±1.4 |
| 16 | 16 | Not Sampled |
| 19 | 16 | 2.6 ±1.3 |
| 18 | 18 | 2.1 ±1.1 |
| 17 | 24 | Not Sampled |
| 15 | 30 | 1.5 ±0.9 |
| 14 | 48 | 3.3 ±1.5 |

| Tomatoes Location | Concentration[d] |
|---|---|
| 2 | 0.017 ±0.004 |
| 13 | 0.025 ±0.008 |
| 1 | 0.070 ±0.009 |
| 3 | 0.022 ±0.004 |
| 6 | 0.036 ±0.006 |
| 12a | 0.036 ±0.009 |
| 12b | 0.034 ±0.013 |
| 4 | 0.021 ±0.010 |
| 16 | 0.024 ±0.004 |
| 17 | 0.0087 ±0.0022 |
| 15 | 0.020 ±0.004 |

| Corn Location | Concentration[d] |
|---|---|
| 9 | 0.0025 ± 0.0004 |
| 3 | 0.0065 ± 0.0008 |
| 8 | 0.0052 ± 0.0007 |
| 6 | 0.0082 ± 0.0026 |
| 5 | 0.0012 ± 0.0002 |
| 11 | 0.0026 ± 0.0005 |
| 7 | 0.0073 ± 0.0009 |
| 19 | 0.0030 ± 0.0008 |
| 14 | 0.0039 ± 0.0007 |

| Soybeans Location | Concentration[d] |
|---|---|
| 9 | 0.14 ±0.02 |
| 10 | 0.0070 ±0.0016 |
| 8 | 0.14 ±0.02 |
| 5 | 0.014 ±0.002 |
| 7 | 0.037 ±0.005 |
| 14 | 0.081 ±0.011 |

**Apples**

| Location | Concentration[d] |
|---|---|
| 1 | 0.011 ±0.002 |
| 19 | 0.024 ±0.004 |
| 18 | 0.29 ±0.03 |

**Potatoes, Onions, Turnips**

| Location | Concentration[d] |
|---|---|
| 13 (O) | 0.15 ±0.02 |
| 3 (P) | 0.018 ±0.002 |
| 12 (P) | 0.057 ±0.007 |
| 12 (T) | 0.064 ±0.008 |
| 19 (P) | 0.030 ±0.004 |
| 18 (T) | 0.10 ±0.01 |
| 15 (P) | 0.12 ±0.02 |

**Cabbage and Lettuce**

| Location | Concentration[d] |
|---|---|
| 4 (C) | 0.021 ±0.005 |
| 13 (L) | 0.11 ±0.02 |
| 15 (L) | 0.21 ±0.03 |

**Pumpkins & Green Beans**

| Location | Concentration[d] |
|---|---|
| 12 (GB) | 0.18 ±0.02 |
| 12 (P) | 0.022 ±0.004 |
| 19 (P) | 0.18 ±0.02 |

a. Single sample collected from each location during September or October 1989.
b. To obtain Bq/g, multiply pCi/g by 0.037.
c. Locations (see Figure 19) are listed in order of increasing distance from the center of the FMPC production area (Plant 4).
d. The plus/minus values are the uncertainty in the analytical results at the 95% confidence level.

**TABLE 5**
**URANIUM IN MILK, 1989[a]**

| Month | Total Uranium (pCi/l)[b] FMPC Dairy | Control Dairy[c] |
|---|---|---|
| Jan | <0.7 | <0.7 |
| | <0.7[d] | <0.7[d] |
| | <0.7[e] | <0.7[e] |
| Feb | <0.7 | <0.7 |
| Mar | <0.7 | <0.7 |
| Apr | <0.7 | <0.7 |
| May | <0.7 | <0.7 |
| June | <0.7 | <0.7 |
| July | <0.7 | <0.7 |
| Aug | <0.7 | <0.7 |
| Sept | <0.7 | <0.7 |
| Oct | 12.8 ± 1.8[f] | 1.9 ± 0.31[f] |
| Nov | <0.7 | <0.7 |
| Dec | <0.7 | <0.7 |

a. Unless noted otherwise, all samples analyzed at commercial contract laboratory.
b. To obtain Bq/l, mulitply pCi/l by 0.037.
c Dairy is about 40 km (25 miles) WSW of the FMPC.
d. Analyzed at Argonne National Laboratory.
e. Analyzed at Radiological and Environmental Sciences Laboratory.
f. Incorrect result, please see discussion in Chapter 3, "Milk Sampling Results."

## TABLE 6
## RADON IN AMBIENT AIR, 1989

| Fenceline Locations[a] | 1989 pCi/l[b] | 1988 pCi/l | Background Locations[a] | 1989 pCi/l[b] | 1988 pCi/l | Other Locations[a] | 1989 pCi/l[b] | 1988 pCi/l |
|---|---|---|---|---|---|---|---|---|
| AMS 1 | 0.6 | 0.7 | BKGD 1 | 0.4 | 0.3 | AMS 8 | 0.6 | 0.8 |
| AMS 2 | 0.7 | 1.0 | BKGD 2 | 0.6 | 0.9 | AMS 9 | 0.8 | 0.8 |
| AMS 4 | 0.7 | 0.7 | | | | AMS 10 | 0.9 | 0.8 |
| AMS 6 | 0.9 | 1.0 | | | | AMS 11 | 0.6 | 0.9 |
| AMS 7 | 0.6 | 1.5 | | | | AMS 12 | 0.6 | 0.7 |
| FMPC-A | 0.8 | 1.3 | | | | AMS 13 | 0.7 | 0.5 |
| FMPC-B | 0.8 | 1.7 | | | | RES 1 | 0.8 | 1.3 |
| FMPC-C | 0.7 | 1.4 | | | | RES 2 | 0.9 | 0.9 |
| FMPC-D | 0.5 | 1.1 | | | | RES 3 | 0.8 | 1.0 |
| FMPC-E | 0.7 | 1.2 | | | | | | |
| FMPC-F | 0.7 | 1.1 | | | | | | |
| FMPC-G | 0.8 | 0.9 | | | | | | |
| FMPC-H | 0.6 | 1.0 | | | | | | |
| FMPC-I | 0.7 | 1.7 | | | | | | |
| FMPC-J | 0.5 | 0.9 | | | | | | |
| FMPC-K | 1.0 | 2.1 | | | | | | |
| FMPC-L | 0.8 | 1.3 | | | | | | |
| FMPC-M | 0.8 | 2.0 | | | | | | |
| FMPC-N | 0.8 | 0.8 | | | | | | |
| FMPC-O | 0.8 | 1.3 | | | | | | |
| FMPC-P | 1.0 | 0.9 | | | | | | |

SUMMARY — 1988 & 1989 RESULTS

| Fenceline | | | – Background | | | = Net[c] | | |
|---|---|---|---|---|---|---|---|---|
| Average | 0.74 | 1.2 | Average | 0.50 | 0.62 | Fenceline | 0.24 | 0.60 |
| Std.Dev. | ±0.14 | ± 0.4 | Std. Dev. | ±0.07 | ± 0.43 | Std. Dev. | ±0.15 | ± 0.60 |

a. See Figures 20 and 21.
b. To obtain Bq/l, multiply pCi/l by 0.037.
c. DOE guideline concentration of 3.0 pCi/l above-background as stated in DOE Draft Order 5400.xx, March 18, 1988.

**TABLE 7**
**RADIONUCLIDES DISCHARGED TO THE GREAT MIAMI RIVER, 1989**

| Radionuclide[a] | Total Curies 1988 | Total Curies 1989 | 1989 Average[b] pCi/l | Standard[c] pCi/l | Percent of Standard[d] |
|---|---|---|---|---|---|
| Ac-227 | < 0.016 | < 0.00094 | < 1.0 | 10 | < 10.0 |
| Cesium-137 | < 0.0049 | < 0.0074 | < 7.9 | 3000 | < 0.3 |
| K-40 | < 0.068 | < 0.12 | < 130 | 7000 | < 1.9 |
| Np-237 | < 0.000033 | < 0.000090 | < 0.10 | 30 | < 0.3 |
| Pb-210 | < 0.0066 | < 0.0041 | < 4.4 | 30 | < 14.7 |
| Pu-238 | < 0.000016 | < 0.00007 | < 0.08 | 40 | < 0.2 |
| Pu-239/240 | < 0.000023 | 0.00010 | 0.11 | 30 | 0.4 |
| Radium-226 | < 0.0024 | < 0.0026 | < 2.7 | 100 | < 2.7 |
| Radium-228 | < 0.0021 | < 0.0058 | < 6.2 | 100 | < 6.2 |
| Ru-106 | < 0.032 | < 0.067 | < 71 | 6000 | < 1.2 |
| Strontium-90 | 0.0012 | < 0.00052 | < 0.55 | 1000 | < 0.1 |
| Technetium-99 | 5.9 | < 3.3 | < 3500 | 100000 | < 3.5 |
| Thorium-228 | 0.00032 | < 0.00029 | < 0.31 | 400 | < 0.1 |
| Thorium-230 | 0.00074 | 0.00026 | 0.27 | 300 | 0.1 |
| Thorium-232 | 0.000087 | 0.00073 | 0.78 | 50 | 1.6 |
| Thorium-234 | < 0.079 | 0.28[e] | 300 | 10000 | 3.0 |
| Uranium-234 | 0.24 | 0.22 | 240 | 500 | 48.0 |
| Uranium-235 | 0.012 | 0.011 | 12 | 600 | 2.0 |
| Uranium-236 | 0.011 | 0.0079 | 8.4 | 500 | 1.7 |
| Uranium-238 | 0.28 | 0.28 | 300 | 600 | 50.0 |
| Total | | | | | < 148 |

a. Radionuclide concentrations in the plant effluent discharged to the Great Miami River through the effluent pipeline are determined from monthly or quarterly composites of daily, 24-hour continuous samples at Discharge 001.
b. To obtain Bq/l, multiply pCi/l by 0.037.
c. As stated in DOE Draft Order 5400.xx, March 18, 1988.
d. Percent of standard relates to the average concentration.
e. Calculated value based on radioactive decay equilibrium with uranium-238.

# TABLE 8
## NPDES DATA, 1989
(page 1 of 2)

| Parameter | Units | Monitoring/ Sampling Requirements | Results: Daily Minimum | Results: Daily Maximum | Results: Daily[a] Average | NPDES Permit Limits: Daily Maximum | NPDES Permit Limits: Monthly Average | Percent Compliance[b] |
|---|---|---|---|---|---|---|---|---|
| **Discharge 001 (MH175)** | | | | | | | | |
| Flow Rate | MGD | Continuous | 0.09 | 1.5 | 0.68 | NA[d] | NA | NA |
| pH | S.U. | Daily/Grab | 7.4 | 9.3 | NA | Range = 6.5 to 9.0 | | 99.7 |
| Suspended Solids[c] | mg/l | Wk/24hr Comp | < 2.0 | 127 | 17 | 40 | 20 | 92.2 |
| Oil & Grease | mg/l | Weekly/Grab | < 5.0 | 11 | < 5.1 | 15 | NA | 100.0 |
| Residual Chlorine | mg/l | Weekly/Grab | < 0.02 | 0.10 | < 0.04 | 0.1 | NA | 100.0 |
| | | | | | | Average Percent Compliance | | 99.0 |
| **Discharge 002 (Storm-Sewer Outfall)** | | | | | | | | |
| Flow Rate | MG/Event | Continuous | 0.016 | 0.58 | NA[e] | NA | NA | NA |
| pH | S.U. | Event/Grab | 7.9 | 8.1 | NA[e] | Range = 6.5 to 9.0 | | 100.0 |
| Suspended Solids[c] | mg/l | Event/Grab | 50 | 78 | NA[e] | 100 | 30 | 0.0 |
| Oil & Grease | mg/l | Event/Grab | < 5.0 | 11 | NA[e] | 15 | NA | 100.0 |
| | | | | | | Average Percent Compliance | | 66.7 |
| **Sampling Location 001A (Sewage Treatment Plant)** | | | | | | | | |
| Flow Rate | MGD | Continuous | 0.056 | 0.37 | 0.22 | NA | NA | NA |
| pH | S.U. | Daily/Grab | 7.5 | 8.6 | NA | Range = 6.5 to 9.0 | | 100.0 |
| $BOD_5$[c] | mg/l | Weekly/Grab | 0.0 | 12 | 2.9 | 40 | 20 | 100.0 |
| Suspended Solids[c] | mg/l | Wk/24hr Comp | 1.0 | 13 | 3.9 | 40 | 20 | 100.0 |
| Fecal Coliform | #Col/100ml | Weekly/Grab | 0.0 | 1000 | 69[f] | 2000 | 1000[f] | 100.0 |
| $BOD_5$ | kg/d | Weekly/Grab | 0.0 | 9.9 | 2.6 | 10 | 5 | 100.0 |
| Suspended Solids | kg/d | Wk/24hr Comp | 0.5 | 14 | 3.6 | 10 | 5 | 87.5 |
| | | | | | | Average Percent Compliance | | 98.8 |

a. Daily Average is shown as < if more than one quarter of the values were less than the detection limit.
b. Percent compliance is determined by comparing the noncompliances with the compliance opportunities.
c. Flow-weighted averages
d Not Applicable
e. Two overflow events: March 31 and April 4. Averages would not reflect actual conditions.
f. Geometric mean

## TABLE 8
## NPDES DATA, 1989
(page 2 of 2)

| Parameter | Units | Monitoring/ Sampling Requirements | Results: Daily Minimum | Results: Daily Maximum | Results: Daily Average[a] | NPDES Permit Limits: Daily Maximum | NPDES Permit Limits: Monthly Average | Percent Compliance[b] |
|---|---|---|---|---|---|---|---|---|
| **Sampling Locations 001B & C (Combined General Sump & Clearwell)** | | | | | | | | |
| Flow Rate | MGD | Continuous | 0.019 | 0.53 | 0.055 | NA | NA | NA |
| Suspended Solids | kg/day | Wk/24hr Comp | <0.10 | 23 | < 1.2 | 12.8 | 6.2 | 96.8 |
| Chromium (+6) | kg/day | Wk/24hr Comp | <0.0001 | 0.003 | < 0.0003 | 0.008 | 0.004 | 100.0 |
| Chromium (total) | kg/day | Wk/24hr Comp | <0.0001 | 0.010 | < 0.0006 | 0.102 | 0.050 | 100.0 |
| Iron | kg/day | Wk/24hr Comp | 0.0006 | 1.8 | 0.061 | 0.85 | 0.41 | 96.8 |
| Nickel | kg/day | Wk/24hr Comp | <0.0002 | 0.049 | < 0.0029 | 0.256 | 0.124 | 100.0 |
| Copper | kg/day | Wk/24hr Comp | 0.0001 | 0.010 | 0.0014 | 0.051 | 0.025 | 100.0 |
| | | | | | | | Average Percent Compliance | 98.9 |
| **Sampling Location 001D (Lift Station)** | | | | | | | | |
| Flow Rate | MGD | Continuous | 0.003 | 1.1 | 0.23 | NA | NA | NA |
| Suspended Solids[c] | mg/l | Weekly/Grab | < 2.0 | 172 | < 24 | 100 | 30 | 93.7 |
| Oil & Grease | mg/l | Weekly/Grab | < 5.0 | 16 | < 5.5 | 15 | NA | 98.1 |
| | | | | | | | Average Percent Compliance | 95.7 |
| **Sampling Location 001E (Bioreactor)** | | | | | | | | |
| Flow Rate | MGD | Continuous | 0.014 | 0.19 | 0.11 | NA | NA | NA |
| Nitrate-Nitrogen | kg/d | Wk/24hr Comp | 0.02 | 81 | 4.9 | 124 | 62 | 100.0 |
| Ammonia-Nitrogen | kg/d | Wk/24hr Comp | 0.03 | 2.6 | 0.30 | 18 | 12 | 100.0 |
| | | | | | | | Average Percent Compliance | 100.0 |
| | | | | | | | Total Compliance | 98. |

a. Daily Average is shown as < if more than one quarter of the values were less than the detection limit.
b. Percent compliance is determined by comparing the noncompliances with the compliance opportunities.
c. Flow-weighted averages

## TABLE 9
## RADIONUCLIDES IN SURFACE WATER, 1989

| Sampling Location[b] | Number of Samples | Concentration pCi/l[a] Minimum | Maximum | Average | Standards[c] pCi/l | Percent of Standard Minimum | Maximum | Average |
|---|---|---|---|---|---|---|---|---|
| Total Uranium | | | | | | | | |
| W1 | 51 | 0.95 | 2.2 | 1.4 | 550 | 0.17 | 0.40 | 0.25 |
| W3 | 51 | 1.0 | 2.4 | 1.5 | 550 | 0.18 | 0.44 | 0.27 |
| W4 | 38 | 1.0 | 2.2 | 1.5 | 550 | 0.18 | 0.40 | 0.27 |
| W5 | 50 | 0.47 | 2.4 | 0.86 | 550 | 0.09 | 0.44 | 0.16 |
| W7 | 28 | 2.3 | 36 | 6.4 | 550 | 0.42 | 6.5 | 1.2 |
| W8 | 20 | 1.4 | 26 | 4.5 | 550 | 0.25 | 4.7 | 0.82 |
| W9 | 47 | 0.61 | 4.3 | 1.5 | 550 | 0.11 | 0.78 | 0.27 |
| W10 | 31 | 1.6 | 640 | 70 | 550 | 0.29 | 116 | 13 |
| W11 | 24 | 2.8 | 28 | 6.7 | 550 | 0.51 | 5.1 | 1.2 |
| Ra-226[d] | | | | | | | | |
| W1 | 12 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W3 | 12 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W4 | 10 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W5 | 6 | < 0.001 | < 0.001 | < 0.001 | 100 | < 0.001 | < 0.001 | < 0.001 |
| W7 | 8 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W8 | 4 | < 0.001 | 0.001 | 0.001 | 100 | < 0.001 | 0.001 | 0.001 |
| Ra-228[d] | | | | | | | | |
| W1 | 12 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W3 | 12 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W4 | 10 | < 0.001 | 0.003 | < 0.001 | 100 | < 0.001 | 0.003 | < 0.001 |
| W5 | 6 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W7 | 8 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| W8 | 4 | < 0.001 | 0.001 | < 0.001 | 100 | < 0.001 | 0.001 | < 0.001 |
| Cs-137[d] | | | | | | | | |
| W1 | 2 | < 8.0 | < 8.9 | < 8.5 | 3,000 | < 0.27 | < 0.30 | < 0.28 |
| W3 | 2 | < 8.0 | < 10 | < 9.0 | 3,000 | < 0.27 | < 0.33 | < 0.30 |
| W4 | 2 | < 9.1 | < 11 | < 10 | 3,000 | < 0.30 | < 0.37 | < 0.33 |
| Sr-90[d] | | | | | | | | |
| W1 | 2 | 0.15 | 0.19 | 0.17 | 1,000 | 0.015 | 0.019 | 0.017 |
| W3 | 2 | < 0.17 | < 0.20 | < 0.19 | 1,000 | < 0.017 | < 0.020 | < 0.019 |
| W4 | 2 | 0.17 | < 0.19 | < 0.18 | 1,000 | 0.017 | < 0.019 | < 0.018 |
| Tc-99[d] | | | | | | | | |
| W1 | 2 | < 18 | < 21 | < 19 | 100,000 | < 0.018 | < 0.021 | < 0.019 |
| W3 | 2 | < 16 | < 18 | < 17 | 100,000 | < 0.016 | < 0.018 | < 0.017 |
| W4 | 2 | < 17 | < 18 | < 18 | 100,000 | < 0.017 | < 0.018 | < 0.018 |

a. To obtain Bq/l, multiply pCi/l by 0.037.
b. See Figure 27.
c. Standards as listed in DOE Order 5400.xx, 3-18-88. The standards are based on drinking 730 liters (about 200 gallons) of water per year. The FMPC compares data from the Great Miami River and Paddy's Run to these standards even though neither is designated as a public water supply by OEPA (OEPA Regulations, Vol. 1, 3475-1-21).
d. Samples are composited as follows: one-month composites of daily samples from W1 and W3; one-month composites of weekly samples from W4, two-month composites of weekly samples from W5, and one-month composites of all available weekly samples from W7. Semiannual composites were used for those isotopes where two samples are recorded.

## TABLE 10
## ANION CONCENTRATIONS IN SURFACE WATER, 1989

| Parameter | Sampling Location[a] | Number of Samples | Concentration mg/l Minimum | Concentration mg/l Maximum | Concentration mg/l Average | Standards[b] mg/l | Percent of Standard Minimum | Percent of Standard Maximum |
|---|---|---|---|---|---|---|---|---|
| Fluoride | W1 | 51 | 0.3 | 1.3 | 0.44 | 1.8 | 17 | 72 |
| | W3 | 51 | 0.2 | 1.1 | 0.43 | | 11 | 61 |
| | W4 | 38 | 0.2 | 1.2 | 0.44 | | 11 | 67 |
| | W5 | 12 | 0.2 | 0.4 | 0.23 | | 11 | 22 |
| | W7 | 10 | 0.1 | 0.7 | 0.26 | | 5.6 | 39 |
| | W8 | 6 | 0.1 | 0.3 | 0.18 | | 5.6 | 17 |
| | W9 | 12 | 0.2 | 0.4 | 0.25 | | 11 | 22 |
| | W10 | 10 | 0.2 | 0.8 | 0.41 | | 11 | 44 |
| | W11 | 7 | 0.2 | 0.6 | 0.25 | | 11 | 33 |
| Nitrate-Nitrogen | W1 | 51 | 1.7 | 11 | 4.8 | 10 | 17 | 110 |
| | W3 | 51 | 1.4 | 11 | 4.7 | | 14 | 110 |
| | W4 | 38 | 1.3 | 11 | 4.8 | | 13 | 110 |
| | W5 | 12 | 0.2 | 3.9 | 2.2 | | 2.0 | 39 |
| | W7 | 10 | 0.1 | 3.4 | 2.2 | | 1.0 | 34 |
| | W8 | 6 | 0.1 | 1.5 | 0.43 | | 1.0 | 15 |
| | W9 | 12 | < 0.1 | 4.1 | 2.0 | | <1.0 | 41 |
| | W10 | 10 | 0.1 | 4.2 | 2.3 | | 1.0 | 42 |
| | W11 | 7 | 1.3 | 3.9 | 2.9 | | 13 | 39 |
| Chloride | W1 | 51 | 17 | 90 | 52 | 250 | 6.8 | 36 |
| | W3 | 51 | 18 | 92 | 52 | | 7.2 | 37 |
| | W4 | 38 | 22 | 78 | 47 | | 8.8 | 31 |
| | W5 | 12 | 9 | 53 | 30 | | 3.6 | 21 |
| | W7 | 10 | 4 | 29 | 14 | | 1.6 | 12 |
| | W8 | 6 | 6 | 28 | 14 | | 2.4 | 11 |
| | W9 | 12 | 8 | 37 | 25 | | 3.2 | 15 |
| | W10 | 10 | 7 | 38 | 23 | | 2.8 | 15 |
| | W11 | 7 | 7 | 33 | 21 | | 2.8 | 13 |

a. See Figure 27 for sampling locations.
b. Neither the Great Miami River (sampling locations W1, W3, and W4) nor Paddy's Run (sampling locations W5, W7, W8, W9, W10, and W11) are designated as a Public Water supply (OEPA Regulations, Vol. 1, 3745-1-21). Nevertheless, the FMPC compares the surface water data to Public Use standards published by OEPA (3745-1-07).

**TABLE 11**
**pH VALUE FOR SURFACE WATER, 1989**

| Sampling[a] Location | Number of Samples | pH Value Minimum | pH Value Maximum | Number of Values Outside Acceptable Range[b] |
|---|---|---|---|---|
| W1 | 51 | 8.0 | 8.8 | 0 |
| W3 | 51 | 8.0 | 8.8 | 0 |
| W4 | 38 | 8.0 | 8.8 | 0 |
| W5 | 50 | 7.6 | 8.2 | 0 |
| W7 | 28 | 7.6 | 8.3 | 0 |
| W8 | 20 | 7.5 | 8.3 | 0 |
| W9 | 47 | 7.8 | 8.5 | 0 |
| W10 | 31 | 7.8 | 8.8 | 0 |
| W11 | 24 | 7.8 | 8.5 | 0 |

a. See Figure 27 for sampling locations.
b. Acceptable range, as defined in OEPA regulation 3745-1-31, is 6.5 - 9.0.

# TABLE 12
## RADIOISOTOPES IN GREAT MIAMI RIVER, PADDY'S RUN, AND OUTFALL DITCH SEDIMENTS, 1989

| | | Radionuclide Concentration pCi/g (dry weight)[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location[b] | Statistic[c] | Pu-238 | Pu-239/240 | Ra-224 | Ra-226 | Ra-228 | Tc-99 | Th-228 | Th-230 | Th-232 | U-234 | U-235/236 | U-238 |
| Paddy's Run above Storm-Sewer Outfall | N | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 |
| | MIN | < 0.012 | < 0.012 | 0.21 | < 0.21 | < 0.17 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | 0.46 | 0.056 | 0.82 | 1.1 | 0.73 | < 0.90 | 4.3 | 2.6 | 2.1 | 2.2 | < 1.0 | 6.6 |
| | AVG | < 0.024 | < 0.016 | 0.44 | 0.63 | 0.43 | < 0.90 | < 1.1 | < 1.1 | < 1.0 | < 1.1 | < 1.0 | < 1.2 |
| Storm-Sewer Outfall | N | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| | MIN | < 0.012 | < 0.012 | 0.29 | 0.39 | < 0.33 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | 1.0 | 1.0 | 1.9 | 2.4 | 2.0 | < 0.90 | 1.2 | 3.4 | 1.1 | 19 | 1.8 | 22 |
| | AVG | < 0.06 | < 0.07 | 0.70 | 0.76 | 0.68 | < 0.90 | < 1.0 | < 1.5 | < 1.0 | 4.3 | < 1.1 | 5.0 |
| Paddy's Run below Storm-Sewer Outfall | N | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 |
| | MIN | < 0.012 | < 0.012 | < 0.032 | < 0.038 | < 0.15 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | 0.032 | 0.097 | 0.92 | 1.3 | 1.0 | 0.96 | 6.6 | 11 | 1.3 | 3.6 | < 1.0 | 3.9 |
| | AVG | < 0.015 | < 0.016 | 0.41 | 0.50 | 0.42 | < 0.90 | < 1.2 | < 1.3 | < 1.0 | < 1.1 | < 1.0 | < 1.1 |
| Great Miami River above FMPC Effluent Line | N | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | MIN | < 0.012 | < 0.012 | 0.53 | 0.57 | < 0.67 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | < 0.012 | 0.014 | 0.71 | 0.81 | 0.54 | 0.95 | < 1.0 | 1.7 | 1.1 | < 1.0 | < 1.0 | < 1.0 |
| | AVG | < 0.012 | < 0.013 | 0.61 | 0.65 | < 0.57 | < 0.94 | < 1.0 | < 1.2 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Great Miami River below FMPC Effluent Line, above Paddy's Run | N | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | MIN | < 0.012 | < 0.012 | 0.34 | 0.40 | 0.28 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | < 0.012 | < 0.012 | 0.46 | 0.59 | 0.43 | 0.98 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | AVG | < 0.012 | < 0.012 | 0.38 | 0.47 | 0.34 | < 0.93 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Great Miami River below Paddy's Run | N | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | MIN | < 0.012 | < 0.012 | 0.46 | 0.51 | 0.33 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | MAX | < 0.012 | < 0.012 | 0.56 | 0.74 | 0.59 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| | AVG | < 0.012 | < 0.012 | 0.51 | 0.62 | 0.46 | < 0.90 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |

a. Multiply pCi/g by 0.037 to obtain Bq/g.
b. See Figure 31 for sample locations.
c. N = Number of samples taken along each interval.

## TABLE 13
## URANIUM CONCENTRATION IN FISH, 1988 & 1989

| Sampling[a] Location | Family[b] | Number of Samples | | Concentration pCi/g[c,d] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Minimum | | Maximum | | Average | |
| | | 1988 | 1989 | 1988 | 1989 | 1988 | 1989 | 1988 | 1989 |
| 1 (Upstream) | 1 | 6 | 3 | 0.011 | 0.0036 | 5.3 | 0.0039 | 0.96 | 0.0037 |
| | 2 | 2 | 3 | 0.0036 | 0.0027 | 0.37 | 0.0078 | 0.19 | 0.0045 |
| | 3 | 6 | 4 | 0.0014 | 0.0029 | 0.092 | 0.0073 | 0.023 | 0.0047 |
| | 4 | 8 | 6 | 0.0064 | 0.0061 | 0.42 | 0.014 | 0.062 | 0.012 |
| | 5 | 2 | 3 | 0.0027 | 0.0102 | 0.017 | 0.015 | 0.0098 | 0.013 |
| Summary | | 24 | 19 | 0.0014 | 0.0027 | 5.3 | 0.015 | 0.28 | 0.0080 |
| 2 (Outfall) | 1 | 6 | 0 | 0.15 | NA[e] | 4.6 | NA[e] | 2.4 | NA[e] |
| | 2 | 4 | 7 | 0.44 | 0.0049 | 13.3 | 0.032 | 3.8 | 0.011 |
| | 3 | 4 | 5 | 0.17 | 0.0018 | 1.4 | 0.0052 | 0.70 | 0.0037 |
| | 4 | 9 | 3 | 0.22 | 0.0052 | 9.7 | 0.018 | 2.9 | 0.012 |
| | 5 | 3 | 5 | 0.22 | 0.0052 | 1.1 | 0.023 | 0.53 | 0.013 |
| Summary | | 26 | 20 | 0.15 | 0.0018 | 13.3 | 0.032 | 2.3 | 0.010 |
| 3 (Down-stream) | 1 | 2 | 2 | 0.29 | 0.020 | 3.6 | 0.021 | 2.0 | 0.020 |
| | 2 | 0 | 2 | NA[e] | 0.018 | NA[e] | 0.018 | NA[e] | 0.018 |
| | 3 | 12 | 6 | 0.0036 | 0.0044 | 4.1 | 0.021 | 1.6 | 0.014 |
| | 4 | 2 | 6 | 1.0 | 0.019 | 2.1 | 0.051 | 1.6 | 0.038 |
| | 5 | 0 | 1 | NA[e] | 0.015 | NA[e] | 0.015 | NA[e] | 0.015 |
| Summary | | 16 | 17 | 0.0036 | 0.0044 | 4.1 | 0.051 | 1.7 | 0.024 |

a. See Figure 32.
b. Family:
1 = Cyprinidae (carp)
2 = Catastomidae (carpsucker, redhorse, hogsucker)
3 = Centrarchidae, Sciaenidae (bass, sunfish, drum, sauger, crappie)
4 = Clupeidae (gizzard shad)
5 = Ictaluridae (catfish)
c. All concentrations in dry weight.
d. Multiply by 0.037 to obtain Bq/g (dry wt.).
e. Not Applicable.

**TABLE 14**
**URANIUM CONCENTRATION IN ONSITE WELL WATER, 1989**

| Well Number[b] | Number of Samples | Concentration pCi/l[a] | | Percent of Guideline[c] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 3 | 5.9 | 6.6 | 25 | 30 |
| 2011 | 3 | 0.14 | 0.20 | 0.64 | 0.91 |
| 3001 | 3 | 6.4 | 8.8 | 29 | 40 |
| 3003 | 3 | 2.0 | 6.8 | 9.1 | 31 |
| 3005 | 3 | 2.9 | 5.1 | 13 | 23 |
| 3008 | 3 | 0.41 | 1.9 | 1.9 | 8.7 |
| 3009 | 3 | 0.41 | 2.2 | 1.9 | 10 |
| 3010 | 3 | 1.0 | 4.6 | 4.5 | 21 |
| 4001 | 3 | 0.14 | 0.14 | 0.64 | 0.64 |
| 4008 | 3 | 0.20 | 1.4 | 0.91 | 6.4 |
| 4101 | 4 | 0.20 | 0.27 | 0.91 | 1.2 |
| 4102 | 4 | 0.068 | 0.27 | 0.31 | 1.2 |
| 4103 | 4 | 0.068 | 0.14 | 0.31 | 0.64 |

**TABLE 15**
**GROSS ALPHA ACTIVITY IN ONSITE WELL WATER, 1989**

| Well Number[b] | Number of Samples | Concentration pCi/l[a] | | Percent of Guideline[d] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 2 | 6.3 | 20 | 42 | 130 |
| 2011 | 2 | 1.4 | 1.4 | 9.3 | 9.3 |
| 3001 | 2 | 6.8 | 8.1 | 45 | 54 |
| 3003 | 2 | 2.7 | 8.1 | 18 | 54 |
| 3005 | 2 | 3.6 | 4.5 | 24 | 30 |
| 3008 | 2 | <0.45 | 0.90 | <3.0 | 6.0 |
| 3009 | 2 | <0.90 | 2.3 | <6.0 | 15 |
| 3010 | 2 | 4.1 | 8.1 | 27 | 54 |
| 4001 | 2 | <0.45 | 1.8 | <3.0 | 12 |
| 4008 | 2 | <0.45 | 1.4 | <3.0 | 9.3 |
| 4101 | 3 | 1.4 | 1.4 | 9.3 | 9.3 |
| 4102 | 3 | <0.90 | 0.90 | <6.0 | 6.0 |
| 4103 | 3 | <0.90 | 0.90 | <6.0 | 6.0 |

a. To obtain Bq/l, multiply pCi/l by 0.037.
b. See Figure 34 for well locations.
c. For wells 4101, 4102, and 4103, the FMPC uses 22 pCi/l as the guideline for total uranium in drinking water based on DOE Draft Order 5400.xx. For wells 2004 through 4008, the percent of guideline has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.
d. For wells 4101, 4102, and 4103, the FMPC (as directed by DOE) uses the USEPA standard of 15 pCi/l for gross alpha activity in drinking water. For wells 2004 through 4008, the percent of standard has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.

**TABLE 16**
**GROSS BETA ACTIVITY IN ONSITE WELL WATER, 1989**

| Well Number[b] | Number of Samples | Concentration pCi/l[a] | | Percent of Guideline[c] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 2 | 10 | 12 | 20 | 24 |
| 2011 | 2 | 1.8 | 2.7 | 3.6 | 5.4 |
| 3001 | 2 | 7.2 | 8.6 | 14 | 17 |
| 3003 | 2 | 5.9 | 11 | 12 | 22 |
| 3005 | 2 | 6.3 | 6.3 | 13 | 13 |
| 3008 | 2 | 2.7 | 2.7 | 5.4 | 5.4 |
| 3009 | 2 | 2.3 | 14 | 4.6 | 28 |
| 3010 | 2 | 17 | 23 | 34 | 46 |
| 4001 | 2 | 1.4 | 1.4 | 2.8 | 2.8 |
| 4008 | 2 | 1.8 | 2.7 | 3.6 | 5.4 |
| 4101 | 3 | 4.5 | 5.0 | 9.0 | 10 |
| 4102 | 3 | 0.90 | 1.8 | 1.8 | 3.6 |
| 4103 | 3 | 1.4 | 1.8 | 2.8 | 3.6 |

**TABLE 17**
**NITRATE-NITROGEN CONCENTRATION IN ONSITE WELL WATER, 1989**

| Well Number[b] | Number of Samples | Concentration mg/l | | Percent of Guideline[d] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 2 | <0.1 | 0.1 | <1.0 | 1.0 |
| 2011 | 2 | <0.1 | 0.1 | <1.0 | 1.0 |
| 3001 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 3003 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 3005 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 3008 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 3009 | 2 | 0.1 | 1.4 | 1.0 | 14 |
| 3010 | 2 | <0.1 | 0.4 | <1.0 | 4.0 |
| 4001 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 4008 | 2 | <0.1 | <0.1 | <1.0 | <1.0 |
| 4101 | 3 | <0.1 | 0.8 | <1.0 | 8.0 |
| 4102 | 3 | <0.1 | 0.2 | <1.0 | 2.0 |
| 4103 | 3 | <0.1 | 0.1 | <1.0 | 1.0 |

a. To obtain Bq/l, multiply pCi/l by 0.037.
b. See Figure 34 for well locations.
c. For wells 4101, 4102, and 4103, the FMPC (as directed by DOE) uses the USEPA standard of 50 pCi/l for gross beta activity in drinking water. For wells 2004 through 4008, the percent of standard has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.
d. For wells 4101, 4102, and 4103, the FMPC uses the USEPA standard of 10 mg/l for nitrate-nitrogen concentration in drinking water as specified in 40 CFR Part 141, National Primary Drinking Water Standard. For wells 2004 through 4008, the percent of standard has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.

**TABLE 18**
**SULFATE CONCENTRATION IN ONSITE WELL WATER, 1989**

| Well Number[a] | Number of Samples | Concentration mg/l | | Percent of Guideline[b] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 2 | 62 | 93 | 25 | 37 |
| 2011 | 2 | 79 | 110 | 32 | 44 |
| 3001 | 2 | 42 | 55 | 17 | 22 |
| 3003 | 2 | 49 | 64 | 20 | 26 |
| 3005 | 2 | 72 | 76 | 29 | 30 |
| 3008 | 2 | <10 | 26 | < 4.0 | 10 |
| 3009 | 2 | 41 | 60 | 16 | 24 |
| 3010 | 2 | 430 | 660 | 170 | 260 |
| 4001 | 2 | <10 | 69 | < 4.0 | 28 |
| 4008 | 2 | <10 | <10 | < 4.0 | < 4.0 |
| 4101 | 3 | 85 | 110 | 34 | 44 |
| 4102 | 3 | 14 | 70 | 5.6 | 28 |
| 4103 | 3 | 35 | 43 | 14 | 17 |

**TABLE 19**
**CHLORIDE CONCENTRATION IN ONSITE WELL WATER, 1989**

| Well Number[a] | Number of Samples | Concentration mg/l | | Percent of Guideline[c] | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 2004 | 2 | 17 | 30 | 6.8 | 12 |
| 2011 | 2 | 24 | 25 | 9.6 | 10 |
| 3001 | 2 | 17 | 21 | 6.8 | 8.4 |
| 3003 | 2 | 23 | 23 | 9.2 | 9.2 |
| 3005 | 2 | 24 | 30 | 9.6 | 12 |
| 3008 | 2 | 19 | 21 | 7.6 | 8.4 |
| 3009 | 2 | 17 | 23 | 6.8 | 9.2 |
| 3010 | 2 | 42 | 67 | 17 | 27 |
| 4001 | 2 | 30 | 37 | 12 | 15 |
| 4008 | 2 | 11 | 12 | 4.4 | 4.8 |
| 4101 | 3 | 33 | 34 | 13 | 14 |
| 4102 | 3 | 13 | 23 | 5.2 | 9.2 |
| 4103 | 3 | 12 | 13 | 4.8 | 5.2 |

a. See Figure 34 for well locations.
b. For wells 4101, 4102, and 4103, the FMPC uses the USEPA standard of 250 mg/l for sulfate concentration in drinking water as specified in 40 CFR Part 143, National Secondary Drinking Water Standard. For wells 2004 through 4008, the percent of standard has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.
c. For wells 4101, 4102, and 4103, the FMPC uses the USEPA standard of 250 mg/l for chloride concentration in drinking water as specified in 40 CFR Part 143, National Secondary Drinking Water Standard. For wells 2004 through 4008, the percent of standard has been calculated for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.

**TABLE 20**
**pH VALUE FOR ONSITE WELL WATER, 1989**

| Well Number[a] | Number of Samples | pH Value Minimum | pH Value Maximum | Number of Values Outside Acceptable Range[b] |
|---|---|---|---|---|
| 2004 | 2 | 7.5 | 7.7 | 0 |
| 2011 | 2 | 7.4 | 7.6 | 0 |
| 3001 | 2 | 7.6 | 7.6 | 0 |
| 3003 | 2 | 7.5 | 8.0 | 0 |
| 3005 | 2 | 7.5 | 7.5 | 0 |
| 3008 | 2 | 8.1 | 8.3 | 0 |
| 3009 | 2 | 7.6 | 8.0 | 0 |
| 3010 | 2 | 6.9 | 7.1 | 0 |
| 4001 | 2 | 7.4 | 7.5 | 0 |
| 4008 | 2 | 7.5 | 7.5 | 0 |
| 4101 | 3 | 7.3 | 7.7 | 0 |
| 4102 | 3 | 7.4 | 7.6 | 0 |
| 4103 | 3 | 7.4 | 7.5 | 0 |

a. See Figure 34 for well locations.
b. For wells 4101, 4102, and 4103, the FMPC uses the USEPA range of 6.5 to 8.5 for pH of drinking water as specified in 40 CFR Part 143, National Secondary Drinking Water Standard. For wells 2004 through 4008, the acceptable range is provided for reference purposes only. These wells do not supply potable water, but are used for monitoring groundwater quality only.

## TABLE 21
## URANIUM CONCENTRATION IN OFFSITE WELL WATER, 1989

| Well Number[c] | Number of Samples | Concentration pCi/l[a] Minimum | Maximum | Average | Percent of Guideline[b] Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1 | 11 | 0.068 | 0.34 | 0.17 | 0.31 | 1.5 |
| 3 | 11 | 0.068 | 0.27 | 0.17 | 0.31 | 1.2 |
| 4 | 12 | 1.1 | 1.7 | 1.4 | 5.0 | 7.7 |
| 5 | 12 | 1.3 | 1.8 | 1.5 | 5.9 | 8.2 |
| 7 | 12 | 1.0 | 1.4 | 1.1 | 4.5 | 6.4 |
| 8 | 12 | 0.47 | 0.74 | 0.60 | 2.1 | 3.4 |
| 9 | 12 | 0.74 | 1.1 | 1.0 | 3.4 | 5.0 |
| 10 | 12 | 0.41 | 0.81 | 0.52 | 1.9 | 3.7 |
| 11 | 12 | 0.81 | 1.3 | 1.1 | 3.7 | 5.9 |
| 12 | 11 | 130 | 240 | 170 | 590[d] | 1100[d] |
| 13 | 12 | 0.27 | 0.54 | 0.37 | 1.2 | 2.5 |
| 14 | 12 | 0.68 | 1.1 | 0.88 | 3.1 | 5.0 |
| 15 | 12 | 160 | 220 | 190 | 730[d] | 1000[d] |
| 16 | 11 | 0.34 | 0.61 | 0.52 | 1.5 | 2.8 |
| 17 | 11 | 20 | 36 | 27 | 91[d] | 160[d] |
| 18 | 11 | 0.27 | 0.47 | 0.34 | 1.2 | 2.1 |
| 19 | 11 | 0.068 | 0.14 | 0.12 | 0.31 | 0.64 |
| 21 | 12 | 0.20 | 0.27 | 0.25 | 0.91 | 1.2 |
| 22 | 11 | 0.68 | 1.0 | 0.79 | 3.1 | 4.5 |
| 23 | 12 | 0.41 | 0.68 | 0.58 | 1.9 | 3.1 |
| 24 | 12 | 0.27 | 0.54 | 0.40 | 1.2 | 2.5 |
| 25 | 4[e] | 0.20 | 0.41 | 0.27 | 0.91 | 1.9 |
| 26 | 12 | 0.068 | 0.20 | 0.14 | 0.31 | 0.91 |
| 27 | 9 | 0.34 | 0.81 | 0.50 | 1.5 | 3.7 |
| 28 | 4[e] | 0.54 | 0.61 | 0.57 | 2.5 | 2.8 |
| 29 | 12 | 0.81 | 1.5 | 1.1 | 3.7 | 6.8 |
| 30 | 11 | 0.27 | 0.54 | 0.38 | 1.2 | 2.5 |
| 32 | 8[f] | 0.068 | 0.14 | 0.093 | 0.31 | 0.64 |
| 34 | 3[g] | 0.74 | 0.95 | 0.83 | 3.4 | 4.3 |
| 35 | 3[g] | 1.1 | 1.4 | 1.2 | 5.0 | 6.4 |

a. To obtain Bq/l, multiply pCi/l by 0.037.
b. The FMPC uses 22 pCi/l as the guideline for total uranium in drinking water based on DOE Draft Order 5400.xx.
c. See Figure 39 for well locations.
d. These wells are not sources of potable water; they are used only for monitoring purposes.
e. Scheduled for quarterly sampling.
f. Owner of this well joined the monitoring program during May 1989.
g. Owners of these wells joined the monitoring program during October 1989.

## TABLE 22
## METALS IN OFFSITE WELL WATER, 1989[a]

| Well Number[b] | Ag[c] | As[c] | Ba[c] | Ca | Cd[c] | Cr[c] | Cu[c] | Fe[c] | K | Mg | Mn[c] | Na | Ni | Pb[c] | Se[c] | Zn[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Concentration mg/l | | | | | | | | | | | | | | | |
| 1 | < 0.02 | 0.019 | 0.38 | 78 | < 0.001 | < 0.002 | 0.008 | 3.4 | 1.1 | 22 | 0.019 | 17 | < 0.003 | < 0.001 | 0.011 | 0.016 |
| 3 | < 0.02 | 0.016 | 0.44 | 77 | < 0.001 | < 0.002 | 0.026 | 3.6 | 0.90 | 23 | 0.020 | 31 | 0.008 | 0.001 | 0.008 | 0.008 |
| 4 | < 0.02 | < 0.002 | 0.068 | 140 | < 0.001 | < 0.002 | 0.028 | 0.033 | 2.5 | 63 | 0.004 | 48 | < 0.003 | < 0.001 | 0.009 | 0.035 |
| 5 | < 0.02 | < 0.002 | 0.053 | 170 | < 0.001 | < 0.002 | 0.016 | 0.89 | 2.0 | 56 | 0.083 | 31 | 0.005 | < 0.001 | 0.005 | 0.035 |
| 7 | < 0.02 | < 0.002 | 0.081 | 120 | < 0.001 | < 0.002 | 0.022 | 2.2 | 2.4 | 31 | 0.17 | 9.2 | < 0.003 | 0.001 | 0.014 | 0.099 |
| 8 | < 0.02 | < 0.002 | 0.068 | 98 | < 0.001 | < 0.002 | 0.011 | 0.040 | 3.0 | 27 | 0.14 | 17 | < 0.003 | < 0.001 | 0.011 | 0.009 |
| 9 | < 0.02 | < 0.002 | 0.095 | 86 | < 0.001 | < 0.002 | 0.014 | 0.12 | 4.1 | 27 | 0.56 | 31 | < 0.003 | < 0.001 | 0.011 | 0.012 |
| 10 | < 0.02 | < 0.002 | 0.058 | 110 | < 0.001 | < 0.002 | 0.009 | 2.8 | 2.2 | 26 | 0.23 | 12 | < 0.003 | < 0.001 | 0.010 | 0.009 |
| 11 | < 0.02 | < 0.002 | 0.053 | 83 | < 0.001 | < 0.002 | 0.082 | 0.036 | 2.7 | 22 | 0.003 | 26 | 0.006 | 0.002 | 0.011 | 0.16 |
| 12 | < 0.02 | 0.002 | 0.049 | 90 | < 0.001 | < 0.002 | 0.015 | 0.058 | 3.7 | 22 | 0.003 | 13 | < 0.003 | 0.003 | 0.010 | 0.26 |
| 13 | < 0.02 | < 0.002 | 0.050 | 94 | < 0.001 | < 0.002 | 0.026 | < 0.025 | 2.8 | 26 | 0.028 | 19 | < 0.003 | < 0.001 | 0.007 | 0.008 |
| 14 | < 0.02 | < 0.002 | 0.12 | 120 | < 0.001 | < 0.002 | 0.005 | 0.80 | 6.0 | 31 | 0.28 | 22 | < 0.003 | < 0.001 | 0.012 | 0.026 |
| 15 | < 0.02 | < 0.002 | 0.051 | 90 | < 0.001 | < 0.002 | 0.047 | < 0.025 | 3.0 | 22 | 0.008 | 12 | < 0.003 | < 0.001 | 0.009 | 0.050 |
| 16 | < 0.02 | 0.002 | 0.12 | 120 | < 0.001 | < 0.002 | 0.008 | 2.0 | 2.7 | 33 | 0.37 | 38 | < 0.003 | < 0.001 | 0.012 | 0.011 |
| 17 | < 0.02 | 0.002 | 0.072 | 97 | < 0.001 | < 0.002 | 0.010 | 2.5 | 3.0 | 22 | 0.38 | 13 | < 0.003 | 0.001 | 0.010 | 0.016 |
| 18 | < 0.02 | < 0.002 | 0.083 | 120 | < 0.001 | < 0.002 | 0.016 | 3.4 | 3.1 | 29 | 0.14 | 12 | < 0.003 | < 0.001 | 0.011 | 0.008 |
| 19 | < 0.02 | 0.071 | < 0.03 | 55 | < 0.001 | < 0.002 | 0.005 | 0.81 | 370 | 28 | 0.12 | 51 | 0.009 | < 0.001 | 0.034 | 0.016 |
| 21 | < 0.02 | 0.002 | 0.086 | 110 | < 0.001 | < 0.002 | 0.013 | 2.5 | 2.7 | 26 | 0.26 | 11 | 0.005 | < 0.001 | 0.010 | 0.034 |
| 22 | < 0.02 | < 0.002 | 0.047 | 96 | < 0.001 | < 0.002 | 0.013 | < 0.025 | 2.9 | 23 | 0.049 | 13 | 0.006 | < 0.001 | 0.010 | 0.022 |
| 23 | < 0.02 | < 0.002 | < 0.03 | 1 | < 0.001 | < 0.002 | 0.007 | 0.043 | 1.2 | < 0.10 | < 0.002 | 160 | 0.006 | < 0.001 | 0.016 | < 0.004 |
| 24 | < 0.02 | < 0.002 | 0.056 | 120 | < 0.001 | < 0.002 | 0.014 | < 0.025 | 1.8 | 32 | 0.088 | 6.2 | < 0.003 | < 0.001 | 0.009 | 0.020 |
| 26 | < 0.02 | 0.004 | 0.081 | 110 | < 0.001 | < 0.002 | 0.011 | 3.5 | 2.2 | 27 | 0.32 | 7.6 | 0.007 | < 0.001 | 0.010 | 0.052 |
| 29 | < 0.02 | < 0.002 | 0.063 | 82 | < 0.001 | < 0.002 | 0.007 | 2.2 | 2.6 | 22 | 0.19 | 9.1 | < 0.003 | < 0.001 | 0.011 | 0.005 |
| 30 | < 0.02 | < 0.002 | 0.052 | 86 | < 0.001 | < 0.002 | 0.033 | 0.025 | 2.6 | 22 | 0.002 | 15 | < 0.003 | 0.002 | 0.011 | 0.005 |
| 32 | < 0.02 | 0.021 | < 0.03 | 82 | < 0.001 | < 0.002 | 0.008 | 1.3 | 71 | 28 | 0.48 | 10 | < 0.003 | < 0.001 | 0.014 | 0.004 |

a. Data are from one sample collected from each well during July 1989.
b. Samples were not taken at wells 2, 20, 25, 27, 28, and 31.
c. EPA Drinking Water Guidelines: (Taken from 40 CFR Part 141 National Interim Primary Drinking Water Regulations-Support B-Maximum Contaminant Levels July 1984). Ag=0.05 mg/l; As=0.05 mg/l; Ba=1.0 mg/l; Cd=0.01 mg/l; Cr=0.05 mg/l; Pb=0.05 mg/l; Se=0.01 mg/l.
d. EPA Drinking Water Guidelines: (Taken from 40 CFR Part 143 National Secondary Drinking Water Regulations-Section 143.3-Secondary Maximum Contaminant Levels July 1984). Cu=1.0 mg/l; Fe=0.3 mg/l; Mn=0.05 mg/l; Zn=5.0 mg/l.

## TABLE 23
## SUMMARY OF RADIATION DOSE DUE TO 1989 EMISSIONS[a]

| Type of Dose | Organ | Dose Equivalent (50-yr Committed) mrem | (mSv) | Standard[b] mrem | % of Standard |
|---|---|---|---|---|---|
| I. Individual | | | | | |
| A. Maximum individual dose from all pathways, all nuclides except radon due to air emissions[c,d] | Effective | 1.2 | (0.012) | 100 | 1.2 |
| | Whole Body[e] | 0.0009 | (0.000009) | 25 | 0.0036 |
| | Bone Endosteum | 1.0 | (0.01) | 75 | 1.3 |
| | Pulmonary | 9.6 | (0.096) | 75 | 12.8 |
| B. Ingestion[f] | | | | | |
| Vegetables: | | | | | |
| Lettuce (18 kg/yr) | Effective | 0.46 | (0.0046) | 100 | 0.46 |
| Green Beans (45 kg/yr) | Effective | 1.2 | (0.012) | 100 | 1.2 |
| Great Miami River Water (2 l/day) | Effective | 0.027 | (0.00027) | 100 | 0.027 |
| | Bone Endosteum | 0.40 | (0.0040) | 5000 | 0.0012 |
| Great Miami River Fish (4.4 kg/yr) | Effective | 0.024 | (0.00024) | 100 | 0.024 |
| | Bone Endosteum | 0.39 | (0.0039) | 5000 | 0.0078 |
| Offsite Well Water[g] Well 15 (2 l/day) | Effective | 32 | (0.32) | 100 | 32.0 |
| | Bone Endosteum | 520 | (5.2) | 5000 | 10.4 |
| C. Direct External[h] | Whole Body | 12 | (0.12) | 100 | 12.0 |
| D. Radon | | | | | |
| Maximum dose to public at FMPC fence-line 8760 hrs/yr | Effective | 72 | (0.72) | ...[i] | |
| II. 80 km Population Dose[c] | | person-rem | person-Sv | | |
| Total committed dose equivalent for $2.6 \times 10^6$ people living within 80 km. | Effective | 21 | (0.21) | ...[i] | |
| | Whole Body | 0.016 | (0.00016) | ...[i] | |
| III. Other Background Sources of Dose[j] | | | | | |
| A. Natural Radioactivity | | mrem/yr | (mSv/yr) | | |
| 1. Radon in homes | | 200 | (2.0) | | |
| 2. Other natural background radiation: cosmic radiation plus natural terrestrial isotopes, both external and internal. | | 100 | (1.0) | | |
| B. Medical diagnosis[k] | | 50 | (0.5) | | |
| C. Consumer products | | 10 | (0.1) | | |
| D. Atmospheric weapons tests | | 4.6 | (0.046) | | |

a. Including dose from all radionuclides listed in Table 24.
b. Standards are as included in DOE Draft Order 5400.xx, "Radiation Protection of the Public and the Environment," dated March 18, 1988. Also incorporated are the air emission dose standards of regulation 40 CFR 61, Subpart H (NESHAP).
c. See Table 26 for inhalation dose estimates at all air monitoring stations.
d. Dose estimates provided by ORNL using AIRDOS computer code with estimated pit emissions not included in the total airborne emissions. With estimated pit emissions included, the dose estimates were (in mrem): 5.2 effective, 0.0037 whole body, 27 bone endosteum, and 34 pulmonary. The 80 km population dose estimate was 63 person-rem (see Chapter Four).
e. Whole body dose equivalent provided by ORNL.
f. Dose equivalent based on environmental measurements according to ICRP 26/30 methodology. ICRP 26/30 based on 50-year commitment dose conversion factors.
g. Well 15 contained the highest concentration of uranium measured offsite in 1989. Dose calculations based on maximum hypothetical dose from drinking this water. This well is not now a source of drinking water.
h. Calculated from measured exposure rate at nearest residence west of the K-65 Silos, using a calibrated pressurized ionization chamber.
i. There are no applicable standards.
j. From NCRP-93, "Ionizing Radiation Exposure of the Population of the United States."
k. Medical dose estimates are population averages and will not necessarily be applicable to each individual.

**TABLE 24**
**ESTIMATED AIRBORNE EMISSIONS FOR FMPC, 1989**

| Radionuclide | Total Curies | Measured [a] | Estimated [b] Waste Pits [c] | Estimated [b] All other Sources [d] |
|---|---|---|---|---|
| U-234 | 0.00495 | 0.000256 | 0.00148 | 0.00321 |
| U-235 | 0.000572 | 0.0000131 | 0.000396 | 0.000163 |
| U-236 | 0.000426 | 0.0000124 | 0.000252 | 0.000162 |
| U-238 | 0.00989 | 0.000257 | 0.00648 | 0.00315 |
| Sr-90 | 0.0000148 | 0.00000095 | 0.00000348 | 0.0000104 |
| Tc-99 | 0.00087 | 0.0000286 | 0.000491 | 0.00035 |
| Ru-106 | 0.0000701 | 0.00000531 | 0.00 | 0.0000648 |
| Cs-137 | 0.0000492 | 0.00000283 | 0.0000154 | 0.000031 |
| Ba-137m | 0.0000492 | 0.00000283 | 0.0000154 | 0.000031 |
| Ra-226 | 0.000193 | 0.000000114 | 0.000192 | 0.000001 |
| Ra-228 | 0.0000293 | 0.000000454 | 0.0000239 | 0.0000049 |
| Th-228 | 0.0000867 | 0.00000473 | 0.0000310 | 0.000051 |
| Th-230 | 0.00362 | 0.0000141 | 0.00345 | 0.00016 |
| Th-232 | 0.0000327 | 0.000000747 | 0.0000239 | 0.0000081 |
| Th-234 | 0.0162 | 0.000792 | 0.00648 | 0.00892 |
| Pa-234m | 0.0162 | 0.000792 | 0.00648 | 0.00892 |
| Np-237 | 0.00000589 | 0.000000102 | 0.00000448 | 0.00000131 |
| Pu-238 | 0.0000024 | 0.000000105 | 0.000000979 | 0.00000132 |
| Pu-239 | 0.0000143 | 0.000000846 | 0.00000247 | 0.000011 |
| Pu-240 | 0.00000552 | 0.000000218 | 0.00000247 | 0.00000283 |
| Pu-241 | 0.0000617 | 0.00000320 | 0.0000168 | 0.0000417 |
| Pu-242 | 0.0000000026 | 0.0000000000459 | No Estimate | 0.00000000253 |

a. Measured emissions include 33 monitored stacks (dust collectors) that operated during 1989. They are measured by continuous samplers.
b. Estimated emissions do not include nonroutine releases.
c. Fugitive emissions from the waste pits.
d. Includes unmonitored stacks, building vents, laboratory emissions, scrubbers, and cooling towers.

## TABLE 25
## ESTIMATED POPULATION DISTRIBUTION WITHIN 80 KM (50 MILES) OF THE FMPC[a]

| Compass Sector | 0-1.6 km (0-1 mi) | 1.6-3.2 km (1-2 mi) | 3.2-4.8 km (2-3 mi) | 4.8-6.4 km (3-4 mi) | 6.4-8 km (4-5 mi) | 8-16 km (5-10 mi) | 16-32 km (10-20 mi) | 32-48 km (20-30 mi) | 48-64 km (30-40 mi) | 64-80 km (40-50 mi) |
|---|---|---|---|---|---|---|---|---|---|---|
| N | 7 | 64 | 77 | 108 | 125 | 1008 | 16676 | 7161 | 16737 | 12369 |
| NNE | 5 | 57 | 65 | 111 | 300 | 13702 | 7595 | 8288 | 31333 | 78291 |
| NE | 8 | 206 | 120 | 129 | 317 | 38550 | 45545 | 96440 | 189514 | 317133 |
| ENE | 16 | 106 | 2714 | 5 | 47 | 31258 | 17295 | 31720 | 13520 | 25702 |
| E | 24 | 62 | 119 | 89 | 235 | 34442 | 53951 | 39591 | 17675 | 10403 |
| ESE | 16 | 68 | 137 | 206 | 292 | 38965 | 160794 | 72536 | 24073 | 13277 |
| SE | 8 | 69 | 107 | 153 | 192 | 52064 | 273363 | 94394 | 26815 | 15853 |
| SSE | 15 | 67 | 88 | 256 | 591 | 20714 | 218659 | 55517 | 9311 | 8685 |
| S | 8 | 69 | 97 | 384 | 620 | 8376 | 32804 | 34309 | 9475 | 9575 |
| SSW | 9 | 77 | 154 | 290 | 354 | 4814 | 9492 | 7718 | 6022 | 9695 |
| SW | 9 | 85 | 143 | 129 | 130 | 1171 | 15147 | 10752 | 3708 | 4916 |
| WSW | 17 | 84 | 142 | 216 | 296 | 7081 | 3749 | 7092 | 7243 | 5908 |
| W | 9 | 79 | 135 | 215 | 270 | 2488 | 3650 | 10355 | 5805 | 16385 |
| WNW | 8 | 66 | 102 | 161 | 213 | 1596 | 4242 | 6469 | 4255 | 12060 |
| NW | 12 | 63 | 99 | 154 | 219 | 1091 | 1398 | 3222 | 26366 | 9417 |
| NNW | 17 | 64 | 102 | 186 | 316 | 1538 | 12963 | 4921 | 48181 | 13725 |
| TOTAL | 188 | 1286 | 4401 | 2792 | 4517 | 258858 | 877323 | 490485 | 440033 | 563394 |

Total for all sectors: 2,643,277

a. Based on an extrapolation from 1980 census data by Geographic Data Systems Section, Computing and Telecommunications Division at Oak Ridge National Laboratory, May 1989.

**TABLE 26**
**ESTIMATED COMMITTED EFFECTIVE DOSE EQUIVALENTS AND PULMONARY DOSE EQUIVALENTS AT AIR MONITORING STATIONS, 1989**

| AMS | Organs[a] | 50 Year Dose Commitment, mrem 1988 | 1989 | % of Standard[b] |
|---|---|---|---|---|
| 1 | Effective | 2.9 | 0.33 | 0.33 |
| | Pulmonary | 23 | 2.5 | 3.3 |
| 2 | Effective | 3.1 | 0.40 | 0.40 |
| | Pulmonary | 23 | 3.2 | 4.3 |
| 3 | Effective | 4.0 | 0.68 | 0.68 |
| | Pulmonary | 32 | 5.4 | 7.2 |
| 4 | Effective | 1.0 | 0.27 | 0.27 |
| | Pulmonary | 7.3 | 2.0 | 2.7 |
| 5 | Effective | 1.0 | 0.24 | 0.24 |
| | Pulmonary | 7.7 | 1.8 | 2.4 |
| 6 | Effective | 1.1 | 0.40 | 0.40 |
| | Pulmonary | 8.5 | 3.1 | 4.1 |
| 7 | Effective | 0.7 | 0.27 | 0.27 |
| | Pulmonary | 4.9 | 2.1 | 2.8 |
| 8 | Effective | 5.2 | 0.61 | ...[c] |
| | Pulmonary | 39 | 4.6 | ...[c] |
| 9 | Effective | 7.5 | 1.6 | ...[c] |
| | Pulmonary | 60 | 13 | ...[c] |
| 10 | Effective | 0.5 | 0.23 | 0.23 |
| | Pulmonary | 3.1 | 1.8 | 2.4 |
| 11 | Effective | 0.5 | 0.15 | 0.15 |
| | Pulmonary | 3.4 | 1.2 | 1.6 |
| 12 | Effective | 0.4 | 0.14 | 0.14 |
| | Pulmonary | 2.2 | 1.1 | 1.5 |
| 13 | Effective | 1.1 | 0.14 | 0.14 |
| | Pulmonary | 7.2 | 1.1 | 1.5 |
| 14 | Effective | 0.6 | 0.15 | 0.15 |
| | Pulmonary | 3.6 | 1.2 | 1.6 |

a. The effective dose equivalent is the weighted sum of dose equivalents delivered to the individual organs of the body. Values reported in this table are based on concentrations of radionuclides measured in the air sampled by the various air monitoring stations. These values are very conservative since "less than detectable" concentrations (from Table 2) were included and background radionuclide concentrations were not subtracted.
b. See footnotes in Table 23 for standards.
c. Onsite AMS; standards for dose to public not applicable.

**TABLE 27**
**EXTERNAL RADIATION DOSE, 1989**

| Sampling Location[a] | Dose Rate (µrem/hr) Annual Average | Maximum | Minimum |
|---|---|---|---|
| AMS 1 | 11.71 | 13.48 | 8.66 |
| AMS 2 | 11.49 | 13.10 | 8.50 |
| AMS 3 | 12.49 | 16.12 | 9.09 |
| AMS 4 | 10.60 | 12.59 | 7.93 |
| AMS 5 | 11.02 | 12.68 | 8.03 |
| AMS 6 | 16.81 | 19.71 | 13.14 |
| AMS 7 | 11.33 | 13.18 | 7.56 |
| AMS 8 | 11.29 | 11.59 | 10.71 |
| AMS 9 | 14.01 | 17.47 | 9.46 |
| AMS 10 | 9.13 | 11.00 | 5.84 |
| AMS 11 | 9.46 | 11.83 | 7.54 |
| AMS 12 | 8.80 | 10.64 | 7.69 |
| AMS 13 | 8.73 | 10.73 | 6.21 |
| BKGD[b] | 10.04 | 12.75 | 5.82 |

a. See Figure 9.
b. Background is average of measurements at two locations (BKGD-1 and BKGD-2) between 25 and 40 km from the FMPC.

**TABLE 28**
**DOE QUALITY ASSESSMENT PROGRAM FOR ENVIRONMENTAL RADIONUCLIDE ANALYSES**

FMPC LABORATORIES PERFORMANCE RESULTS FOR 1989

| Sample Type | Sample Number | Units | Uranium Values: FMPC Laboratories | EML[a] | Ratio FMPC Value/EML Value |
|---|---|---|---|---|---|
| Water | 89 - 04 | µg/ml | 0.0130 ± 0.0013 | 0.0130 ± 0.0005 | 1.00 ± 0.11[b] |
| Water | 89 - 09 | µg/ml | 0.0145 ± 0.0010 | 0.0132 ± 0.0004 | 1.10 ± 0.08 |
| Air Filter | 89 - 04 | µg/filter | 0.47 ± 0.08 | 0.268 ± 0.011 | 1.75 ± 0.31[c] |
| | 89 - 04 | µg/filter | 0.44 ± 0.08 | 0.268 ± 0.011 | 1.64 ± 0.31[c] |
| Air Filter | 89 - 09 | µg/filter | 1.06 ± 0.24 | 0.72 ± 0.014 | 1.47 ± 0.16 |
| | 89 - 09 | µg/filter | 1.02 ± 0.11 | 0.72 ± 0.014 | 1.42 ± 0.33 |

a. DOE's Environmental Measurements Laboratory
b. The ± uncertainty for the ratios is equal to: $(F^2 + E^2)^{1/2}/EV$ where F is the ± uncertainty in the FMPC value, E is the ± uncertainty in the EML value, and EV is the EML uranium value.
c. The EML established uranium value for the 89 - 04 air filter sample is evidently incorrect; please see Chapter 5: "Independent Evalutation of FMPC Laboratories."

**TABLE 29**
**USEPA QUALITY ASSURANCE PROGRAM**
**FOR WASTE WATER ANALYSES[a]**

**FMPC LABORATORIES PERFORMANCE EVALUATION FOR 1989**

| Parameter | Units | Values: FMPC Laboratories | Values: True[b] | USEPA Acceptance Limits[c] | USEPA Performance Evaluation[d] |
|---|---|---|---|---|---|
| Ammonia-Nitrogen | mg/l | 13.6 | 13.0 | 10.2 - 15.5 | Acceptable |
| Biochemical Oxygen Demand | mg/l | 61.8 | 59.7 | 41.7 - 85.7 | Acceptable |
| Nitrate-Nitrogen (Brucine Sulfate Method) | mg/l | 9.04 | 8.50 | 6.94 - 10.1 | Acceptable |
| Oil & Grease | mg/l | 18.2 | 19.8 | 10.7 - 24.8 | Acceptable |
| Residual Chlorine | mg/l | 1.82 | 2.00 | 1.35 - 2.53 | Acceptable |
| Total Suspended Solids | mg/l | 41.2 | 41.9 | 33.3 - 46.6 | Acceptable |
| pH | Standard | 7.81 | 7.80 | 7.55 - 7.97 | Acceptable |
| Chromium (Total) | µg/l | 152 | 150 | 118 - 179 | Acceptable |
| Copper | µg/l | 70.2 | 76.2 | 65.4 - 86.0 | Acceptable |
| Iron | µg/l | 700 | 749 | 652 - 859 | Acceptable |
| Nickel | µg/l | 596 | 622 | 547 - 691 | Acceptable |

a. USEPA Discharge Monitoring Report (DMR) Quality Assurance (QA) Program. The FMPC, along with all other National Pollution Discharge Elimination System (NPDES) permit holders, is required to participate in these annual laboratory performance evaluation studies (Section 308(a) of the Clean Water Act).
b. Actual parameter concentrations established by USEPA based on theoretical calculations, or a reference value when necessary.
c. Laboratory measured values which fall within this range are considered acceptable by the USEPA.
d. USEPA DMR-QA Study Number 009 conducted during 1989.

# TABLE 30
## PROFICIENCY ENVIRONMENTAL TESTING QUALITY ASSURANCE PROGRAM FOR WATER ANALYSES
(page 1 of 3)

### SUMMARY OF PERFORMANCE OF FMPC LABORATORIES DURING 1989

| Parameter[a] | Units | Range of True Values | % Recovery[b] | | | Standard Deviations From Mean[c] | | | Percentage Acceptable[d] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Avg | Min | Max | Avg | |
| Ammonia-Nitrogen | mg/l | 0.04 - 2.94 | 88 | 210 | 111 | 0.02 | 1.06 | 0.47 | 100 |
| Biochemical Oxygen Demand | mg/l | 15.2 - 235 | 40 | 325 | 106 | 0.07 | 13.7 | 1.95 | 83 |
| Calcium | mg/l | 2.87 - 26.9 | 87 | 108 | 98 | 0.16 | 1.45 | 0.76 | 100 |
| Chloride | mg/l | 27.7 - 128 | 23 | 104 | 94 | 0.01 | 12.2 | 1.20 | 96 |
| Fluoride | mg/l | 1.09 - 7.72 | 91 | 108 | 99 | 0.01 | 1.51 | 0.55 | 100 |
| Magnesium | mg/l | 1.50 - 10.3 | 91 | 119 | 98 | 0.01 | 2.43 | 0.54 | 100 |
| Nitrate-Nitrogen (Brucine Sulfate Method) | mg/l | 0.14 - 1.71 | 97 | 114 | 105 | 0.02 | 1.52 | 0.43 | 100 |
| Nitrate-Nitrogen (Ion Chromatography Method) | mg/l | 0.16 - 1.71 | 71 | 138 | 98 | 0.06 | 2.27 | 1.00 | 100 |
| Oil & Grease | mg/l | 7.01 - 44.8 | 52 | 172 | 85 | 0.00 | 2.29 | 0.52 | 100 |
| Potassium | mg/l | 6.37 - 19.5 | 92 | 144 | 110 | 0.11 | 5.56 | 1.04 | 96 |
| Residual Chlorine | mg/l | 0.07 - 7.40 | 17 | 162 | 88 | 0.03 | 7.71 | 1.20 | 88 |
| Sodium | mg/l | 29.3 - 78.1 | 91 | 111 | 101 | 0.03 | 1.76 | 0.60 | 100 |

## TABLE 30
## PROFICIENCY ENVIRONMENTAL TESTING
## QUALITY ASSURANCE PROGRAM FOR WATER ANALYSES
(page 2 of 3)

### SUMMARY OF PERFORMANCE OF FMPC LABORATORIES DURING 1989

| Parameter[a] | Units | Range of True Values | % Recovery[b] | | | Standard Deviations From Mean[c] | | | Percentage Acceptable[d] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Avg | Min | Max | Avg | |
| Sulfate | mg/l | 11.4 - 42.5 | 88 | 144 | 104 | 0.03 | 4.87 | 0.84 | 92 |
| Total Suspended Solids | mg/l | 38.5 - 454 | 91 | 112 | 100 | 0.02 | 2.60 | 1.01 | 96 |
| pH | Standard | 4.21 - 9.55 | 102 | 110 | 104 | 0.16 | 1.44 | 0.70 | 100 |
| Arsenic | µg/l | 25.3 - 372 | 73 | 121 | 96 | 0.00 | 1.47 | 0.45 | 100 |
| Barium | µg/l | 290 - 1565 | 95 | 110 | 99 | 0.01 | 1.26 | 0.37 | 100 |
| Cadmium | µg/l | 17.6 - 263 | 77 | 107 | 100 | 0.02 | 1.09 | 0.43 | 100 |
| Chromium (Total) | µg/l | 24.8 - 273 | 93 | 115 | 102 | 0.01 | 1.65 | 0.42 | 100 |
| Chromium (Hexavalent) | µg/l | 19.0 - 372 | 75 | 109 | 94 | 0.06 | 1.51 | 0.58 | 100 |
| Copper | µg/l | 25.7 - 272 | 90 | 120 | 103 | 0.24 | 2.14 | 0.69 | 100 |
| Iron | µg/l | 25.4 - 572 | 84 | 132 | 103 | 0.19 | 2.64 | 0.92 | 92 |
| Lead | µg/l | 29.2 - 491 | 22 | 114 | 99 | 0.03 | 6.47 | 0.76 | 96 |

# TABLE 30
## PROFICIENCY ENVIRONMENTAL TESTING QUALITY ASSURANCE PROGRAM FOR WATER ANALYSES
(page 3 of 3)

### SUMMARY OF PERFORMANCE OF FMPC LABORATORIES DURING 1989

| Parameter[a] | Units | Range of True Values | % Recovery[b] | | | Standard Deviations From Mean[c] | | | Percentage Acceptable[d] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Avg | Min | Max | Avg | |
| Manganese | µg/l | 26.1 - 461 | 91 | 107 | 96 | 0.04 | 1.84 | 0.65 | 100 |
| Nickel | µg/l | 20.0 - 269 | 92 | 126 | 102 | 0.04 | 2.24 | 0.61 | 100 |
| Selenium | µg/l | 11.8 - 192 | 91 | 128 | 106 | 0.01 | 1.58 | 0.55 | 100 |
| Silver | µg/l | 14.7 - 304 | 89 | 119 | 101 | 0.03 | 1.37 | 0.40 | 100 |
| Uranium (Fluorometric Method) | µg/l | 40.2 - 945 | 87 | 112 | 101 | 0.02 | 1.65 | 0.48 | 100 |
| Uranium (Phosphorescence Method) | µg/l | 40.2 - 945 | 90 | 114 | 105 | 0.08 | 3.36 | 1.12 | 96 |
| Zinc | µg/l | 17.5 - 220 | 99 | 141 | 111 | 0.02 | 2.19 | 0.55 | 100 |
| | | | | | | Percentage acceptable for all measurements | | | 98 |

a. There were 23 nitrate-nitrogen measurements performed by ion chromatography. For all other analyses, a total of 24 measurements were made; two each month at differing parameter concentrations.
b. Percent recovery is the FMPC measured value divided by the true parameter concentration multiplied by 100.
c. The standard deviation indicates the closeness of the FMPC measurement result to the mean value reported by Analytical Products Group, Inc., which conducts the testing program. The standard deviation would be 0.00 if the FMPC result and mean value were exactly the same. The mean value is calculated from the results obtained by all laboratories participating in the control program. Any measurement results which are significantly different from the true parameter concentration or statistically different from the majority of results obtained by the other laboratories are not included in evaluating the mean value.
d. This is the percentage of FMPC measurement results for each parameter which met the USEPA "Acceptable" criteria of being within 2.58 standard deviations of the mean value.

# TABLE 31
# SPLIT SAMPLES OF SURFACE AND GROUNDWATER

COMPARISON OF FMPC AND OHIO DEPARTMENT OF HEALTH ANALYTICAL RESULTS FOR 1988

page 1 of 4

| | | GROSS ALPHA | | | GROSS BETA | | | URANIUM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Collected | Location | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/L | ODH pCi/L | Equivalent Results | WMCO pCi/L | ODH pCi/L | Equivalent Results |
| 2-Feb-88 | W1 | 5.4 ± 3.8 | 20 ± 3.8 | NO | 9.5 ± 3.2 | 55 ± 3.4 | NO | 0.95 ± 0.33 | 0.53 ± 0.80 | YES |
| 2-Feb-88 | W3 | 6.8 ± 4.7 | 5.0 ± 7.0 | YES | 11 ± 3.7 | 18 ± 6.3 | YES | 1.2 ± 0.42 | 2.7 ± 1.2 | YES |
| 2-Feb-88 | W4 | 6.3 ± 4.4 | 19 ± 8.7 | YES | 12 ± 4.1 | 24 ± 5.6 | NO | 1.1 ± 0.40 | 1.4 ± 1.0 | YES |
| 2-Feb-88 | W7 | 15 ± 10 | 8.8 ± 1.4 | YES | 14 ± 4.7 | 37 ± 4.0 | NO | 16 ± 5.6 | 3.7 ± 1.4 | NO |
| 2-Feb-88 | W9 | 6.8 ± 4.7 | 14 ± 4.9 | YES | 9.5 ± 3.2 | 19 ± 4.5 | NO | 11 ± 4.0 | 6.7 ± 1.2 | YES |
| 2-Feb-88 | Well #4 | 4.1 ± 2.8 | < 3.0 | YES | 4.1 ± 1.4 | < 4.0 | YES | 1.4 ± 0.49 | 1.7 ± 0.63 | YES |
| 2-Feb-88 | Well #10 | 0.90 ± 0.63 | < 3.0 | YES | 1.8 ± 0.61 | < 4.0 | YES | 0.41 ± 0.14 | < 1.0 | YES |
| 2-Feb-88 | Well #14 | 2.7 ± 1.9 | < 3.0 | YES | 5.0 ± 1.7 | 1.9 ± 0.26 | NO | 0.95 ± 0.33 | < 1.0 | YES |
| 2-Feb-88 | Well #15 | 110 ± 76 | 168 ± 13 | YES | 68 ± 23 | 116 ± 8.0 | NO | 180 ± 63 | 160 ± 5.6 | YES |
| 2-Feb-88 | Well #19 | < 0.45 | < 3.0 | YES | 99 ± 33 | 98 ± 4.6 | YES | 0.068 ± 0.023 | 0.16 ± 0.37 | YES |
| 23-Feb-88 | W1 | 2.3 ± 1.6 | 3.9 ± 1.5 | YES | 5.0 ± 1.7 | 8.0 ± 1.5 | YES | 1.0 ± 0.35 | < 1.0 | YES |
| 23-Feb-88 | W3 | 2.3 ± 1.6 | < 3.0 | YES | 5.4 ± 1.8 | 4.8 ± 3.3 | YES | 1.6 ± 0.56 | < 1.0 | NO |
| 23-Feb-88 | W4 | 2.7 ± 1.9 | < 3.0 | YES | 5.9 ± 2.0 | 6.9 ± 3.0 | YES | 1.3 ± 0.45 | < 1.0 | YES |
| 23-Feb-88 | W7 | 12 ± 8.2 | 5.9 ± 2.8 | YES | 8.6 ± 2.9 | 10 ± 2.9 | YES | 16 ± 5.4 | 6.7 ± 1.2 | NO |
| 23-Feb-88 | W9 | 1.8 ± 1.3 | 4.5 ± 2.9 | YES | 4.5 ± 1.5 | 3.8 ± 3.1 | YES | 2.5 ± 0.87 | 1.5 ± 0.66 | YES |
| 23-Feb-88 | Well #3 | 1.8 ± 1.3 | < 3.0 | YES | 3.2 ± 1.1 | < 4.0 | YES | 0.14 ± 0.047 | < 1.0 | YES |
| 23-Feb-88 | Well #4 | 2.3 ± 1.6 | < 3.0 | YES | 4.1 ± 1.4 | < 4.0 | YES | 1.3 ± 0.45 | 1.0 ± 0.62 | YES |
| 23-Feb-88 | Well #14 | 2.3 ± 1.6 | < 3.0 | YES | 5.0 ± 1.7 | 8.0 ± 2.3 | YES | 0.68 ± 0.23 | < 1.0 | YES |
| 23-Feb-88 | Well #15 | 95 ± 66 | 174 ± 12 | NO | 81 ± 27 | 94 ± 6.6 | YES | 180 ± 61 | 170 ± 6.0 | YES |
| 23-Feb-88 | Well #19 | 3.2 ± 2.2 | < 3.0 | YES | 68 ± 23 | 70 ± 4.1 | YES | 0.068 ± 0.023 | < 1.0 | YES |
| 22-Mar-88 | W1 | 2.3 ± 1.6 | < 3.0 | YES | 3.6 ± 1.2 | 2.6 ± 2.5 | YES | 1.0 ± 0.35 | 1.5 ± 0.58 | YES |
| 22-Mar-88 | W3 | 1.8 ± 1.3 | 0.90 ± 3.6 | YES | 11 ± 3.7 | 1.3 ± 3.3 | NO | 1.5 ± 0.52 | 1.5 ± 0.57 | YES |
| 22-Mar-88 | W4 | 2.7 ± 1.9 | < 3.0 | YES | 10 ± 3.5 | 9.4 ± 2.8 | YES | 1.5 ± 0.52 | 2.3 ± 0.71 | YES |
| 22-Mar-88 | W7 | 5.9 ± 4.1 | 1.6 ± 3.0 | YES | 5.0 ± 1.7 | 4.6 ± 3.0 | YES | 4.6 ± 1.6 | 3.3 ± 0.83 | YES |
| 22-Mar-88 | W9 | 3.2 ± 2.2 | < 3.0 | YES | 3.2 ± 1.1 | 3.4 ± 2.8 | YES | 1.4 ± 0.49 | 1.6 ± 0.60 | YES |
| 22-Mar-88 | Well #4 | Not Analyzed | 2.8 ± 2.5 | | Not Analyzed | 4.3 ± 2.3 | | 1.6 ± 0.56 | 1.5 ± 0.64 | YES |
| 22-Mar-88 | Well #14 | Not Analyzed | < 3.0 | | Not Analyzed | 6.1 ± 2.8 | | 0.8 ± 0.28 | 1.1 ± 0.57 | YES |
| 22-Mar-88 | Well #15 | Not Analyzed | 171 ± 13 | | Not Analyzed | 100 ± 7.5 | | 210 ± 73 | 162 ± 5.7 | YES |
| 22-Mar-88 | Well #19 | Not Analyzed | 3.7 ± 2.5 | | Not Analyzed | 63 ± 3.5 | | 0.27 ± 0.094 | < 1.0 | YES |
| 22-Mar-88 | Well #21 | Not Analyzed | < 3.0 | | Not Analyzed | 1.9 ± 2.8 | | 0.34 ± 0.12 | < 1.0 | YES |

# TABLE 31
## SPLIT SAMPLES OF SURFACE AND GROUNDWATER

COMPARISON OF FMPC AND OHIO DEPARTMENT OF HEALTH ANALYTICAL RESULTS FOR 1988
page 2 of 4

| | | GROSS ALPHA | | | GROSS BETA | | | URANIUM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Collected | Location | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results |
| 19-Apr-88 | W1 | 2.7 ± 1.9 | 2.5 ± 2.3 | YES | 4.5 ± 1.5 | 5.2 ± 3.0 | YES | 1.1 ± 0.38 | 0.42 ± 0.45 | YES |
| 19-Apr-88 | W3 | 1.8 ± 1.3 | 4.0 ± 2.7 | YES | 3.6 ± 1.2 | 8.0 ± 3.0 | NO | 1.3 ± 0.45 | 1.5 ± 0.58 | YES |
| 19-Apr-88 | W4 | 1.4 ± 0.95 | 4.2 ± 2.7 | YES | 3.6 ± 1.2 | 6.3 ± 3.0 | YES | 1.6 ± 0.54 | 1.2 ± 0.52 | YES |
| 19-Apr-88 | W7 | 4.1 ± 2.8 | 4.0 ± 3.0 | YES | 4.5 ± 1.5 | 7.0 ± 3.0 | YES | 3.9 ± 1.3 | 4.5 ± 0.98 | YES |
| 19-Apr-88 | W9 | 1.4 ± 0.95 | 2.5 ± 2.6 | YES | 4.1 ± 1.4 | 1.2 ± 3.0 | YES | 1.4 ± 0.47 | 0.89 ± 0.47 | YES |
| 19-Apr-88 | Well #4 | 3.6 ± 2.5 | 3.0 ± 2.0 | YES | 4.5 ± 1.5 | 7.0 ± 4.0 | YES | 1.8 ± 0.63 | 2.3 ± 0.71 | YES |
| 19-Apr-88 | Well #11 | 1.8 ± 1.3 | 1.8 ± 3.0 | YES | 5.4 ± 1.8 | 4.0 ± 3.2 | YES | 1.0 ± 0.35 | 0.40 ± 0.50 | YES |
| 19-Apr-88 | Well #14 | 2.7 ± 1.9 | 1.7 ± 3.0 | YES | 7.2 ± 2.4 | 4.4 ± 3.1 | YES | 0.88 ± 0.30 | 0.73 ± 0.44 | YES |
| 19-Apr-88 | Well #15 | 120 ± 82 | 131 ± 13 | YES | 59 ± 20 | 105 ± 9.2 | NO | 170 ± 59 | 161 ± 5.70 | YES |
| 19-Apr-88 | Well #19 | 2.7 ± 1.9 | < 3.0 | YES | 68 ± 23 | 72 ± 4.0 | YES | 0.27 ± 0.094 | < 1.0 | YES |
| 24-May-88 | W1 | 1.4 ± 0.95 | < 3.0 | YES | 5.9 ± 2.0 | 9.0 ± 3.0 | YES | 1.1 ± 0.40 | 1.4 ± 0.59 | YES |
| 24-May-88 | W3 | 1.8 ± 1.3 | 6.0 ± 3.0 | YES | 6.8 ± 2.3 | 9.0 ± 3.0 | YES | 1.3 ± 0.45 | 1.0 ± 0.58 | YES |
| 24-May-88 | W4 | 1.4 ± 0.95 | < 3.0 | YES | 7.2 ± 2.4 | 13 ± 3.0 | NO | 1.4 ± 0.47 | 2.2 ± 0.72 | YES |
| 24-May-88 | W8 | 1.4 ± 0.95 | < 3.0 | YES | 4.1 ± 1.4 | 5.0 ± 3.0 | YES | 2.0 ± 0.70 | 1.2 ± 0.55 | YES |
| 24-May-88 | W9 | 1.4 ± 0.95 | 3.0 | NO | 3.6 ± 1.2 | < 4.0 | YES | 1.1 ± 0.38 | 0.4 ± 0.47 | YES |
| 24-May-88 | Well #14 | 3.2 ± 2.2 | < 3.0 | YES | 5.9 ± 2.0 | 9.0 ± 4.0 | YES | 0.95 ± 0.33 | 0.9 ± 0.50 | YES |
| 24-May-88 | Well #15 | 100 ± 73 | 145 ± 15 | YES | 63 ± 21 | 124 ± 9.0 | NO | 210 ± 73 | 170 ± 5.86 | YES |
| 24-May-88 | Well #19 | 3.6 ± 2.5 | 3.0 ± 3.0 | YES | 45 ± 15 | 32 ± 4.0 | YES | 0.34 ± 0.12 | 0.13 ± 0.31 | YES |
| 24-May-88 | Well #22 | 2.3 ± 1.6 | < 3.0 | YES | 4.1 ± 1.4 | 4.0 ± 3.0 | YES | 0.68 ± 0.23 | 0.87 ± 0.49 | YES |
| 21-Jun-88 | W1 | 1.4 ± 0.95 | < 3.0 | YES | 6.3 ± 2.1 | 9.0 ± 3.0 | YES | 0.68 ± 0.23 | 0.58 ± 0.44 | YES |
| 21-Jun-88 | W3 | 2.3 ± 1.6 | < 3.0 | YES | 12 ± 4.0 | 17 ± 4.0 | YES | 1.3 ± 0.45 | 2.0 ± 0.75 | YES |
| 21-Jun-88 | W4 | 2.3 ± 1.6 | < 3.0 | YES | 10 ± 3.5 | 14 ± 3.0 | YES | 1.1 ± 0.38 | 3.0 ± 0.85 | NO |
| 21-Jun-88 | W9 | 0.45 ± 0.32 | < 3.0 | YES | 5.0 ± 1.7 | 9.0 ± 3.0 | YES | 0.34 ± 0.12 | 0.53 ± 0.42 | YES |
| 21-Jun-88 | Well #4 | 2.3 ± 1.6 | 2.0 ± 3.0 | YES | 2.7 ± 0.91 | 6.0 ± 2.0 | NO | 1.0 ± 0.35 | 1.2 ± 0.56 | YES |
| 21-Jun-88 | Well #14 | 4.5 ± 3.2 | < 3.0 | YES | 6.3 ± 2.1 | 8.0 ± 3.0 | YES | 0.88 ± 0.30 | 2.0 ± 0.64 | NO |
| 21-Jun-88 | Well #15 | 100 ± 73 | 143 ± 10 | YES | 50 ± 17 | 155 ± 7.0 | NO | 200 ± 70 | 185 ± 6.1 | YES |
| 21-Jun-88 | Well #19 | 3.2 ± 2.2 | < 3.0 | YES | 45 ± 15 | 45 ± 5.0 | YES | 0.54 ± 0.19 | < 1.0 | YES |
| 21-Jun-88 | Well #29 | 2.7 ± 1.9 | < 3.0 | YES | 3.2 ± 1.1 | 7.0 ± 3.0 | YES | 1.4 ± 0.47 | 2.0 ± 0.63 | YES |

# TABLE 31
# SPLIT SAMPLES OF SURFACE AND GROUNDWATER

COMPARISON OF FMPC AND OHIO DEPARTMENT OF HEALTH ANALYTICAL RESULTS FOR 1988

page 3 of 4

| | | GROSS ALPHA | | | GROSS BETA | | | URANIUM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Collected | Location | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results |
| 19-Jul-88 | W1 | 1.8 ± 1.3 | < 3.0 | YES | 11 ± 3.7 | 9.0 ± 4.0 | YES | 0.68 ± 0.23 | 0.70 ± 0.53 | YES |
| 19-Jul-88 | W3 | 8.6 ± 6.0 | < 3.0 | YES | 36 ± 12 | 42 ± 5.0 | YES | 2.2 ± 0.77 | 3.0 ± 0.82 | YES |
| 19-Jul-88 | W4 | 5.9 ± 4.1 | < 3.0 | YES | 28 ± 9.4 | 38 ± 6.0 | YES | 1.7 ± 0.59 | 1.7 ± 0.65 | YES |
| 19-Jul-88 | W8 | 3.6 ± 2.5 | < 3.0 | YES | 5.0 ± 1.7 | 11 ± 5.0 | YES | 1.5 ± 0.52 | 2.0 ± 0.68 | YES |
| 19-Jul-88 | Well #4 | 2.3 ± 1.6 | 4.0 ± 4.0 | YES | 4.1 ± 1.4 | 7.0 ± 3.0 | YES | 0.95 ± 0.33 | 2.0 ± 0.62 | NO |
| 19-Jul-88 | Well #14 | 3.6 ± 2.5 | 5.0 ± 3.0 | YES | 5.9 ± 2.0 | 6.0 ± 3.0 | YES | 0.81 ± 0.28 | 0.42 ± 0.48 | YES |
| 19-Jul-88 | Well #15 | 110 ± 76 | 159 ± 12 | YES | 68 ± 23 | 148 ± 8.0 | NO | 180 ± 63 | 195 ± 6.3 | YES |
| 19-Jul-88 | Well #18 | 2.3 ± 1.6 | < 3.0 | YES | 3.2 ± 1.1 | < 4.0 | YES | 0.41 ± 0.14 | 0.30 ± 0.39 | YES |
| 19-Jul-88 | Well #19 | < 3.6 | 4.0 ± 3.0 | YES | 77 ± 26 | 156 ± 7.0 | NO | 0.27 ± 0.094 | < 1.0 | YES |
| 23-Aug-88 | W1 | 2.7 ± 1.9 | 2.0 ± 3.0 | YES | 9.5 ± 3.2 | 10 ± 3.0 | YES | 1.0 ± 0.35 | 1.3 ± 0.56 | YES |
| 23-Aug-88 | W3 | 3.2 ± 2.2 | 2.0 ± 3.0 | YES | 18 ± 5.9 | 20 ± 3.0 | YES | 2.2 ± 0.77 | 3.1 ± 0.84 | YES |
| 23-Aug-88 | W4 | 2.3 ± 1.6 | 2.0 ± 3.0 | YES | 17 ± 5.6 | 20 ± 3.0 | YES | 2.0 ± 0.70 | 1.9 ± 0.68 | YES |
| 23-Aug-88 | W8 | 2.3 ± 1.6 | 3.0 ± 3.0 | YES | 3.2 ± 1.1 | 6.0 ± 4.0 | YES | 1.7 ± 0.59 | 4.6 ± 1.5 | NO |
| 23-Aug-88 | Well #4 | 2.7 ± 1.9 | 1.0 ± 3.0 | YES | 4.5 ± 1.5 | 7.0 ± 3.0 | YES | 0.95 ± 0.33 | 1.2 ± 0.54 | YES |
| 23-Aug-88 | Well #13 | 1.4 ± 0.95 | 3.0 ± 3.0 | YES | 9.5 ± 3.2 | 10 ± 4.0 | YES | 0.34 ± 0.12 | 0.63 ± 0.44 | YES |
| 23-Aug-88 | Well #14 | 3.2 ± 2.2 | 5.0 ± 3.0 | YES | 6.3 ± 2.1 | 10 ± 4.0 | YES | 0.81 ± 0.28 | 1.0 ± 0.50 | YES |
| 23-Aug-88 | Well #15 | 110 ± 76 | 135 ± 11 | YES | 90 ± 30 | 119 ± 8.0 | YES | 210 ± 73 | 189 ± 6.0 | YES |
| 23-Aug-88 | Well #19 | 4.1 ± 2.8 | 8.4 ± 3.8 | YES | 180 ± 62 | 210 ± 7.4 | YES | 0.47 ± 0.16 | 0.16 ± 0.31 | YES |
| 22-Sep-88 | W1 | 3.6 ± 2.5 | 4.0 ± 3.0 | YES | 7.2 ± 2.4 | 10 ± 4.0 | YES | 0.95 ± 0.33 | 1.2 ± 0.53 | YES |
| 22-Sep-88 | W3 | 2.7 ± 1.9 | 6.0 ± 4.0 | YES | 8.1 ± 2.7 | 13 ± 4.0 | YES | 1.6 ± 0.56 | 1.6 ± 0.61 | YES |
| 22-Sep-88 | W4 | 3.6 ± 2.5 | 3.0 ± 3.0 | YES | 9.0 ± 3.0 | 14 ± 4.0 | YES | 1.3 ± 0.45 | 1.2 ± 0.52 | YES |
| 20-Sep-88 | Well #3 | 2.7 ± 1.9 | 4.0 ± 3.0 | YES | 2.7 ± 0.9 | 2.0 ± 3.0 | YES | 0.068 ± 0.023 | < 1.0 | YES |
| 22-Sep-88 | Well #4 | 3.6 ± 2.5 | 0.0 ± 3.0 | YES | 3.6 ± 1.2 | 3.0 ± 2.0 | YES | 0.95 ± 0.33 | 1.5 ± 0.60 | YES |
| 22-Sep-88 | Well #14 | 3.6 ± 2.5 | 2.0 ± 3.0 | YES | 6.3 ± 2.1 | 6.0 ± 3.0 | YES | 0.88 ± 0.30 | 0.84 ± 0.46 | YES |
| 22-Sep-88 | Well #15 | 100 ± 73 | 200 ± 10 | NO | 77 ± 26 | 100 ± 10 | YES | 200 ± 70 | 150 ± 0.55 | YES |
| 20-Sep-88 | Well #19 | 4.1 ± 2.8 | 16 ± 4.7 | NO | 190 ± 65 | 210 ± 8.5 | YES | 0.27 ± 0.094 | 0.053 ± 0.23 | YES |

# TABLE 31
## SPLIT SAMPLES OF SURFACE AND GROUNDWATER

COMPARISON OF FMPC AND OHIO DEPARTMENT OF HEALTH ANALYTICAL RESULTS FOR 1988
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| | | GROSS ALPHA | | | GROSS BETA | | | URANIUM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Collected | Location | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results | WMCO pCi/l | ODH pCi/l | Equivalent Results |
| 18-Oct-88 | W1 | 1.8 ± 1.3 | 4.5 ± 3.8 | YES | 7.7 ± 2.6 | 12 ± 3.8 | YES | 1.0 ± 0.35 | 1.7 ± 0.63 | YES |
| 18-Oct-88 | W3 | 3.6 ± 2.5 | 7.2 ± 3.8 | YES | 9.0 ± 3.0 | 15 ± 4.0 | YES | 2.8 ± 0.98 | 3.6 ± 0.88 | YES |
| 18-Oct-88 | W4 | 4.5 ± 3.2 | 3.9 ± 3.2 | YES | 11 ± 3.8 | 6.2 ± 3.5 | YES | 2.0 ± 0.68 | 2.2 ± 0.69 | YES |
| 18-Oct-88 | Well #1 | 1.4 ± 0.95 | < 3.0 | YES | 1.8 ± 0.6 | 2.8 ± 3.3 | YES | 0.27 ± 0.094 | 0.16 ± 0.23 | YES |
| 18-Oct-88 | Well #4 | 1.4 ± 0.95 | 2.5 ± 3.7 | YES | 5.0 ± 1.7 | 7.3 ± 3.1 | YES | 0.81 ± 0.28 | 0.68 ± 0.40 | YES |
| 18-Oct-88 | Well #14 | 2.7 ± 1.9 | < 3.0 | YES | 5.4 ± 1.8 | 7.0 ± 3.0 | YES | 0.74 ± 0.26 | 1.4 ± 0.58 | YES |
| 18-Oct-88 | Well #15 | 110 ± 76 | 160 ± 17 | YES | 95 ± 32 | 130 ± 10 | YES | 180 ± 61 | 220 ± 6.6 | YES |
| 18-Oct-88 | Well #19 | < 0.50 | 5.6 ± 3.4 | NO | 190 ± 64 | 190 ± 7.3 | YES | 0.14 ± 0.047 | 0.52 ± 0.36 | YES |
| 22-Nov-88 | W1 | 1.4 ± 0.95 | 3.0 ± 3.0 | YES | 4.5 ± 1.5 | 6.0 ± 4.0 | YES | 1.0 ± 0.35 | 1.1 ± 0.49 | YES |
| 22-Nov-88 | W3 | 2.3 ± 1.6 | < 3.0 | YES | 6.3 ± 2.1 | 7.0 ± 3.0 | YES | 1.4 ± 0.47 | 1.0 ± 0.50 | YES |
| 22-Nov-88 | W4 | 2.7 ± 1.9 | 4.0 ± 3.0 | YES | 6.3 ± 2.1 | 10 ± 3.0 | YES | 1.1 ± 0.40 | 2.0 ± 0.60 | YES |
| 22-Nov-88 | W9 | 4.5 ± 3.2 | < 3.0 | YES | 6.3 ± 2.1 | 8.0 ± 4.0 | YES | 2.4 ± 0.84 | 2.0 ± 0.60 | YES |
| 22-Nov-88 | Well #4 | 3.2 ± 2.2 | < 3.0 | YES | 4.5 ± 1.5 | 5.0 ± 3.0 | YES | 1.0 ± 0.35 | 2.0 ± 0.60 | NO |
| 22-Nov-88 | Well #14 | 2.7 ± 1.9 | 3.0 ± 2.0 | YES | 5.0 ± 1.7 | 7.0 ± 3.0 | YES | 0.74 ± 0.26 | 0.73 ± 0.41 | YES |
| 22-Nov-88 | Well #15 | 110 ± 76 | 150 ± 15 | YES | 86 ± 29 | 140 ± 9.0 | NO | 190 ± 66 | 190 ± 6.2 | YES |
| 22-Nov-88 | Well #16 | 1.4 ± 0.95 | 1.0 ± 2.0 | YES | 2.7 ± 0.9 | 6.0 ± 3.0 | YES | 0.47 ± 0.16 | 0.73 ± 0.41 | YES |
| 22-Nov-88 | Well #19 | < 2.3 | 8.3 ± 4.0 | NO | 190 ± 65 | 210 ± 7.5 | YES | 0.20 ± 0.070 | 0.10 ± 0.21 | YES |
| 20-Dec-88 | W1 | 1.8 ± 1.3 | 2.5 ± 3.7 | YES | 5.0 ± 1.7 | 7.2 ± 3.2 | YES | 1.1 ± 0.38 | 1.3 ± 0.56 | YES |
| 20-Dec-88 | W3 | 2.7 ± 1.9 | 2.0 ± 3.7 | YES | 5.0 ± 1.7 | 6.2 ± 3.2 | YES | 1.4 ± 0.47 | 1.4 ± 0.55 | YES |
| 20-Dec-88 | W4 | 1.8 ± 1.3 | < 3.0 | YES | 6.8 ± 2.3 | 7.8 ± 3.3 | YES | 1.6 ± 0.56 | 2.3 ± 0.69 | YES |
| 20-Dec-88 | W9 | 0.9 ± 0.63 | 2.1 ± 3.8 | YES | 3.6 ± 1.2 | 4.7 ± 4.0 | YES | 1.1 ± 0.38 | 1.7 ± 0.61 | YES |
| 20-Dec-88 | Well #4 | 1.8 ± 1.3 | 1.3 ± 2.3 | YES | 3.2 ± 1.1 | 4.2 ± 2.7 | YES | 0.95 ± 0.33 | 2.1 ± 0.67 | NO |
| 20-Dec-88 | Well #14 | 1.8 ± 1.3 | 1.7 ± 2.9 | YES | 4.5 ± 1.5 | 4.1 ± 2.8 | YES | 0.74 ± 0.26 | 1.1 ± 0.48 | YES |
| 20-Dec-88 | Well #15 | 120 ± 82 | 140 ± 15 | YES | 86 ± 29 | 130 ± 10 | NO | 190 ± 66 | 210 ± 6.6 | YES |
| 20-Dec-88 | Well #19 | < 2.3 | 3.8 ± 3.1 | YES | 210 ± 70 | 200 ± 7.4 | YES | 0.068 ± 0.023 | 0.21 ± 0.25 | YES |
| 20-Dec-88 | Well #24 | 1.4 ± 0.95 | 3.3 ± 4.5 | YES | 3.6 ± 1.2 | < 4.0 | YES | 0.41 ± 0.14 | 0.58 ± 0.37 | YES |
| | | Percentage Equivalent: 93 % | | | Percentage Equivalent: 84% | | | Percentage Equivalent: 92% | | |

ALL ANALYSES: **90% OF RESULTS EQUIVALENT**

**TABLE 32**
**UNDERGROUND STORAGE TANKS, 1989[a]**

| Tank Number | Capacity (gallons) | Product Stored | Construction | Age (years) | Location | Regulation Applicability |
|---|---|---|---|---|---|---|
| 1 | 1,500 | Gasoline | Fiberglass | 8 | Building 31 | UST |
| 2 | 1,500 | Gasoline | Fiberglass | 8 | Building 31 | UST |
| 3 | 12,250 | Diesel Fuel | Steel | 36 | Building 24B | UST |
| 5 | 200 | Waste Oil | Steel | 36 | Building 31 | RCRA |
| 6 | 1,000 | Gasoline | Steel | 36 | Building 12 | UST |
| 8 | 1,000 | Gasoline | Steel | 36 | Building 31 | UST |
| 9 | 1,000 | Gasoline | Steel | 36 | Building 31 | UST |
| 10 | 3,000 | Gasoline | Steel | 36 | Building 31 | UST |
| 11 | 3,000 | Kerosene | Steel | 36 | Plant 1 Truck Dock | UST |
| 12 | 2,000 | Gasoline | Steel | 36 | Plant 1 Truck Dock | UST |
| 13 | 3,000 | Gasoline | Steel | 36 | Plant 1 Truck Dock | UST |
| 14 | 3,000 | Soluble Oil | Steel | 26 | Plant 6 | UST |

a. Status as of December 31, 1989.

**TABLE 33**
**RCRA ASSESSMENT**
**SITE SPECIFIC PARAMETERS, 1989**

| Parameters | Rationale | Parameters | Rationale |
|---|---|---|---|
| Acetone | B | Methylene Chloride | B |
| Arsenic | A | Nickle | A |
| Aluminum | A | Nitrate | A |
| Barium | A | Phenols | Q |
| Beryllium | A | Silver | A |
| Calcium | A | Sodium | Q |
| Chloride | A | Sulfate | A |
| Chromium | A | Tetrachloroethene | A |
| Cobalt | A | TOC | I |
| Copper | A | Toluene | B |
| Dichloroethane | B | TOX | I |
| Fluoride | A | Trichloroethene | C |
| Iron | A | Vanadium | A |
| Lead | A | Zinc | A |
| Manganese | Q | pH | I |
| Magnesium | A | Specific Conductivity | I |

A Major Constituent of Pit 4
B Unconfirmed analyte found in groundwater sample
C Constituent of Pit 4
I Groundwater Indicator Parameter
Q Groundwater Quality Parameter

Note: This table may be revised pending progressive findings in the RCRA Assessment Program.

**TABLE 34**
**EXTENDED HAZARDOUS SUBSTANCE LIST**
**FMPC RCRA ANNUAL PARAMETERS, 1989**

| Inorganic Analytes | Semivolatile Organic Compounds | Semivolatile Organic Compounds | Pesticide Organic Compounds | Volatile Organic Compounds |
|---|---|---|---|---|
| Aluminum | Phenol | 3-Nitroaniline | alpha-BHC | Chloromethane |
| Antimony | bis(2-Chloroethyl)Ether | Acenaphthene | beta-BHC | Bromomethane |
| Arsenic | 2-Chlorophenol | 2,4-Dinitrophenol | delta-BHC | Vinyl Chloride |
| Barium | 1,3-Dichlorobenzene | 4-Nitrophenol | gamma-BHC | Methylene Chloride |
| Beryllium | 1,4-Dichlorobenzene | Dibenzofuran | (Lindane) | Acetone |
| Cadmium | Benzyl Alcohol | 2,4-Dinitrotoluene | Heptachlor | Carbon Disulfide |
| Calcium | 1,2-Dichlorobenzene | Diethylphthalate | Aldrin | 1,1-Dichloroethane |
| Chromium | 2-Methylphenol | 4-Chlorophenyl- | Heptachlor | 1,1-Dichloroethene |
| Cobalt | bis(2-Chloroisopropyl) | phenylether | epoxide | 1,2-Dichloroethene |
| Copper | Ether | Fluorene | Endosulfan I | Chloroform |
| Iron | 4-Methylphenol | 4-Nitroaniline | Dieldrin | 1,2-Dichloroethane |
| Lead | N-Nitroso-Di-n- | 4,6-Dinitro-2- | 4,4'-DDE | 2-Butanone |
| Magnesium | Propylamine | Methylphenol | Endrin | 1,1,1-Trichloro- |
| Manganese | Hexachloroethane | N-Nitrosodi- | Endosulfan II | methane |
| Mercury | Nitrobenzene | phenylamine | 4,4'-DDD | Carbon |
| Nickel | Isophorone | 4-Bromophenyl- | Endosulfan | Tetrachloride |
| Potassium | 2-Nitrophenol | phenylether | sulfate | Vinyl Acetate |
| Selenium | 2,4-Dimethylphenol | Hexachlorobenzene | 4,4'-DDT | Bromodichloro- |
| Silver | Benzoic Acid | Pentachlorophenol | Methoxychlor | methane |
| Sodium | bis(2-Chloroethoxy) | Phenanthrene | Endrin ketone | 1,2-Dichloro- |
| Thallium | Methane | Anthraene | Chlordane | propane |
| Vanadium | 2,4-Dichlorophenol | Di-n-Butylphthalate | Toxaphene | cis-1,3-Dichloro- |
| Zinc | 1,2,4-Trichlorobenzene | Fluoranthene | Aroclor-1016 | propene |
| Cyanide | Naphthalene | Pyrene | Aroclor-1221 | Trichloroethene |
| Molybdenum | 4-Chloroaniline | Butylbenzylphthalate | Aroclor-1232 | Dibromochloro- |
| | Hexachlorobutadiene | 3,3-Dichlorobenzidine | Aroclor-1248 | methane |
| | 4-Chloro-3-Methylphenol | Benzo(a)Anthraene | Aroclor-1254 | Benzene |
| | 2-Methylnaphthalene | Chrysene | Aroclor-1260 | Trans-1,3-Dichloro- |
| | Hexachlorocyclo- | bis(2-Ethylhexyl) | 1,1,2-Trichloro- | propene |
| | pentadiene | Phthalate | ethane | Bromoform |
| | 2,4,6-Trichlorophenol | Di-n-Octyl Phthalate | 4-Methyl-2- | 2-Hexanone |
| | 2,4,5-Trichlorophenol | Benzo(b)Fluoranthene | Pentanone | Chlorobenzene |
| | 2-Chloronaphthalene | Benzo(k)Fluoranthene | Tetrachloroethene | Ethylbenzene |
| | 2-Nitroaniline | Beno(a)Pyrene | Toluene | Styrene |
| | Dimethyl Phthalate | Indeno(1,2,3-cd)Pyrene | | Total Xylene |
| | Acenaphthylene | Dibenz(a,h)Anthracene | | Chloroethane |
| | 2,6-Dinitrotoluene | Benzo(g,h,i)Perylene | | |

APPENDIX B

# 1987-1989 Monitoring Data Presented as Bar Graphs

To help indentify trends, many of the summary data for the last three years are presented in the form of bar charts.

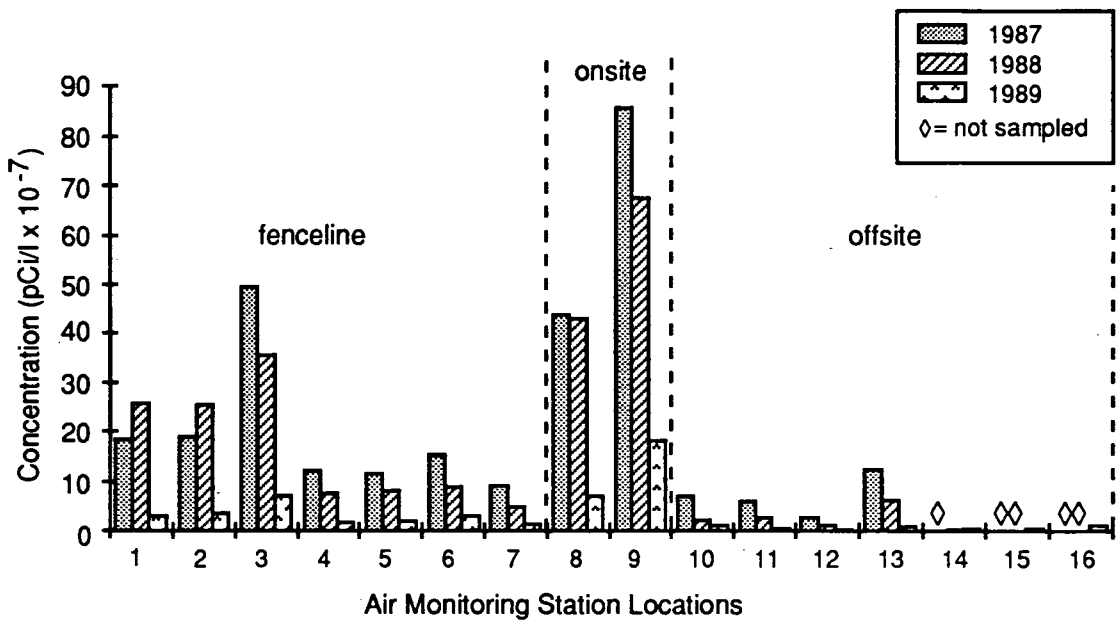


Figure 10. Average Uranium Concentrations in Air, 1987 to 1989

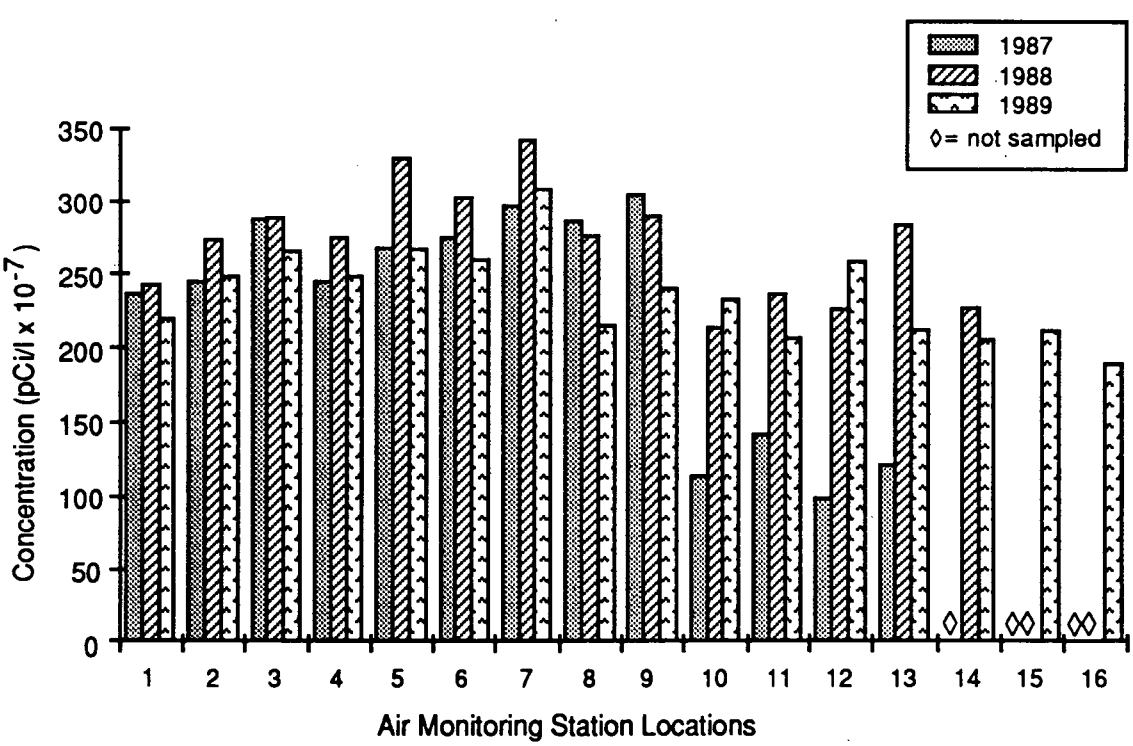


Figure 11. Average Gross Beta Activity in Air, 1987 to 1989

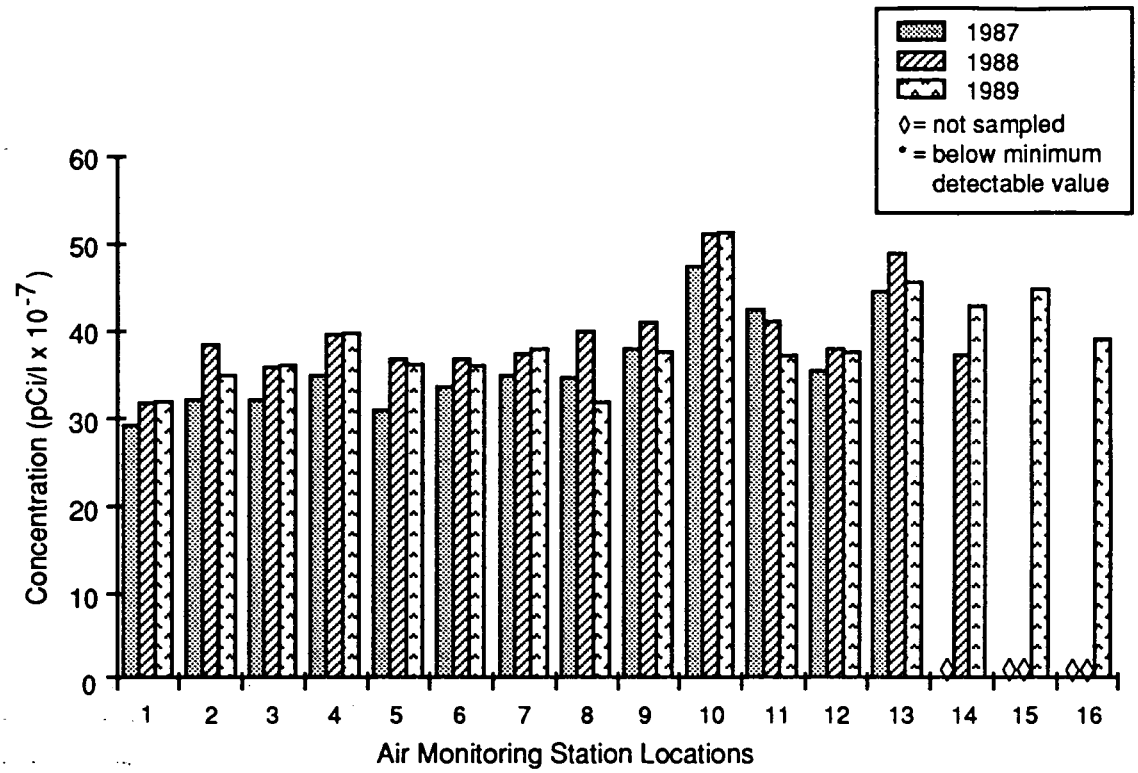


Figure 12. Average Particulate Concentrations in Air, 1987 to 1989

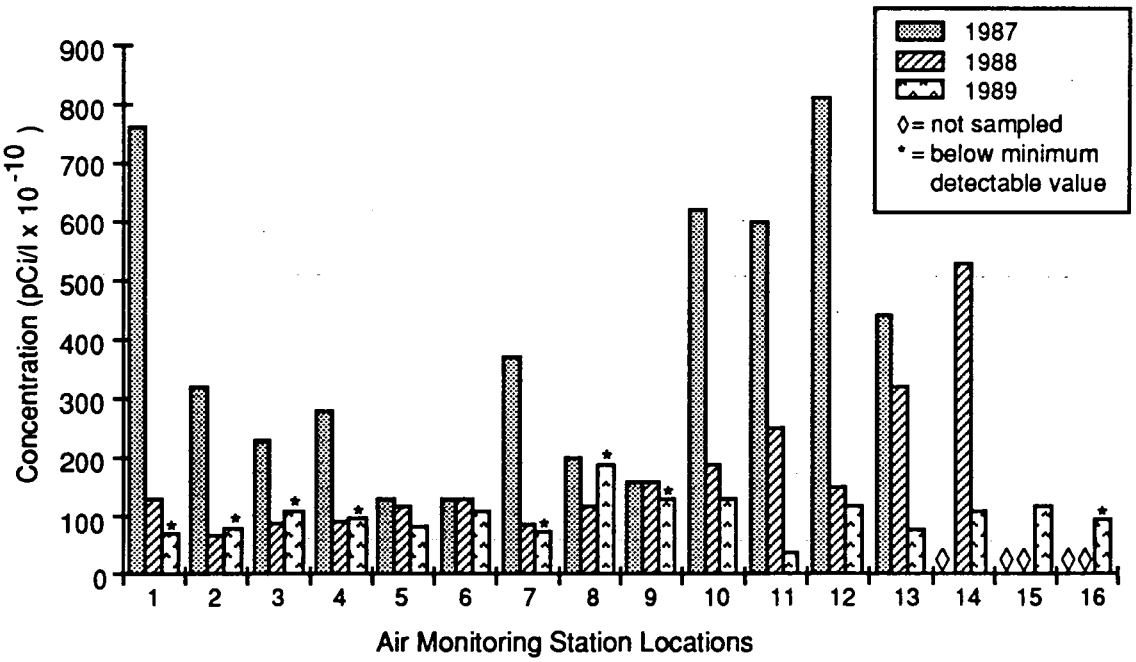


Figure 13. Average Thorium-228 Concentrations in Air, 1987 to 1989

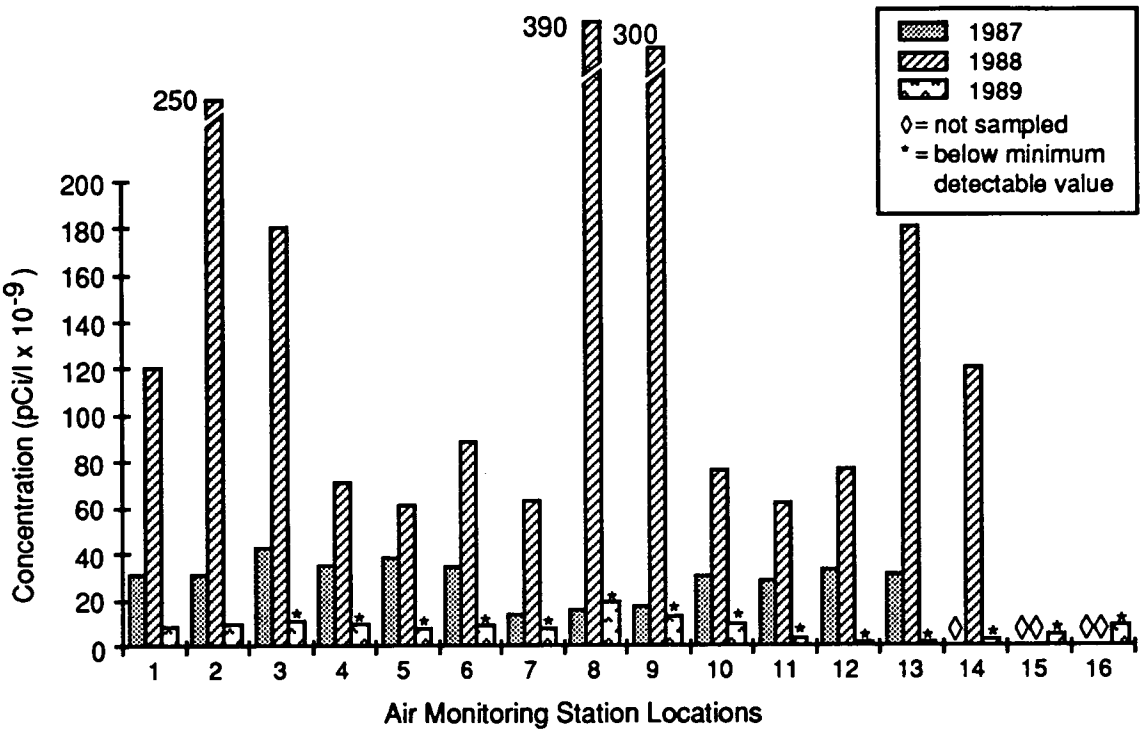


Figure 14. Average Thorium-230 Concentrations in Air, 1987 to 1989

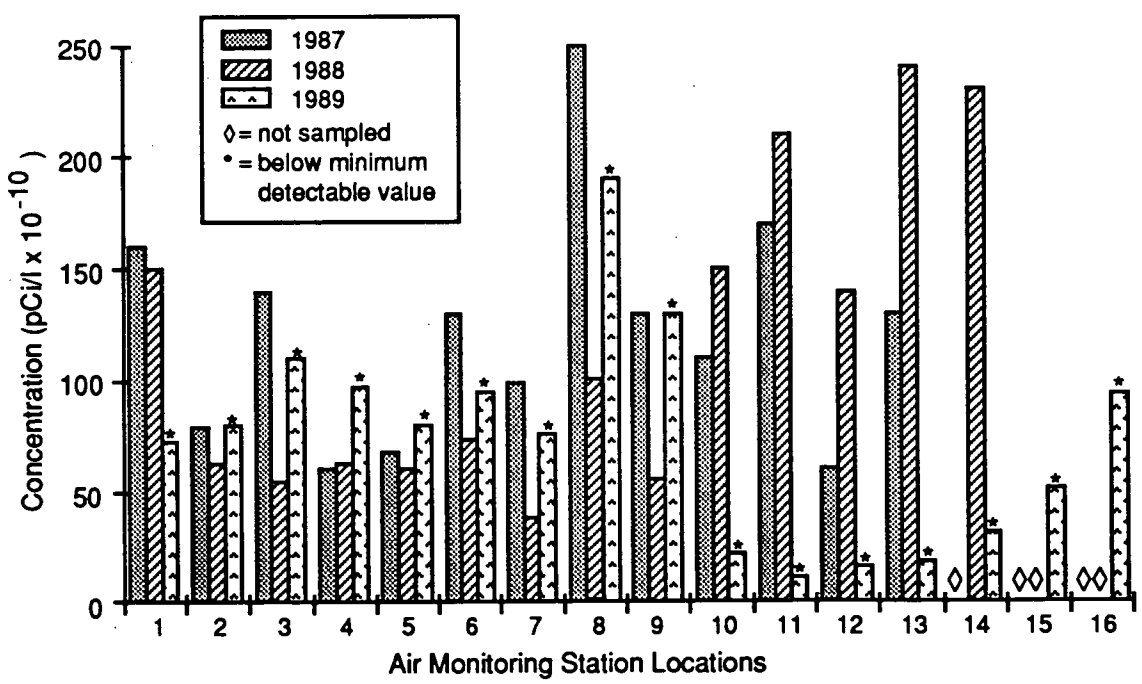


Figure 15. Average Thorium–232 Concentrations in Air, 1987 to 1989

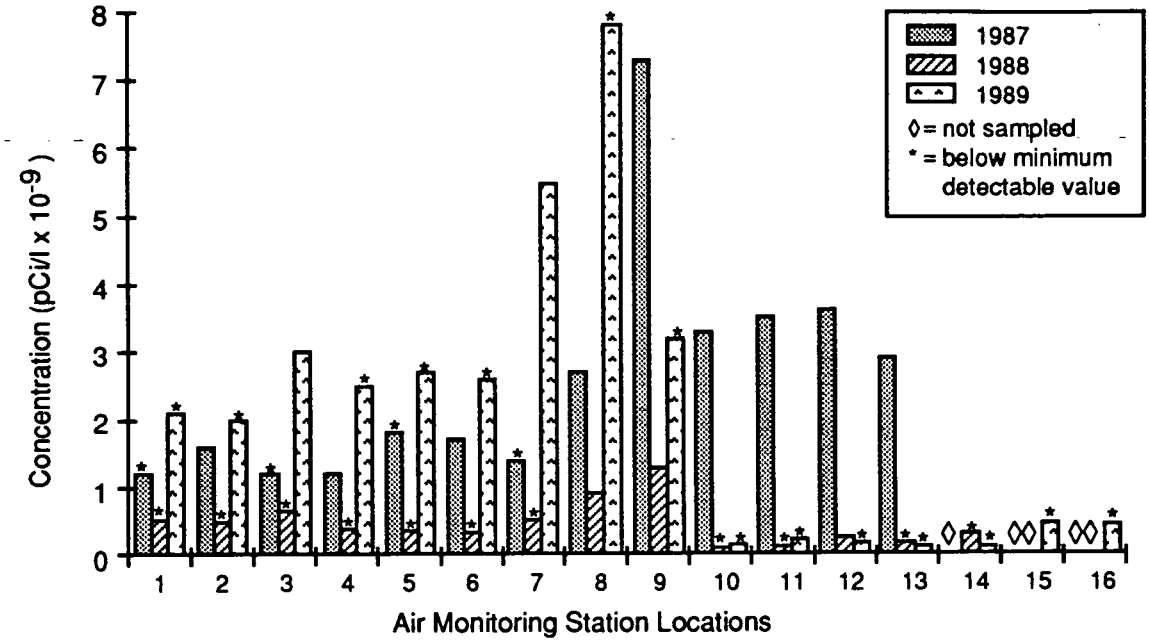


Figure 16. Average Plutonium-238 Concentrations in Air, 1987 to 1989

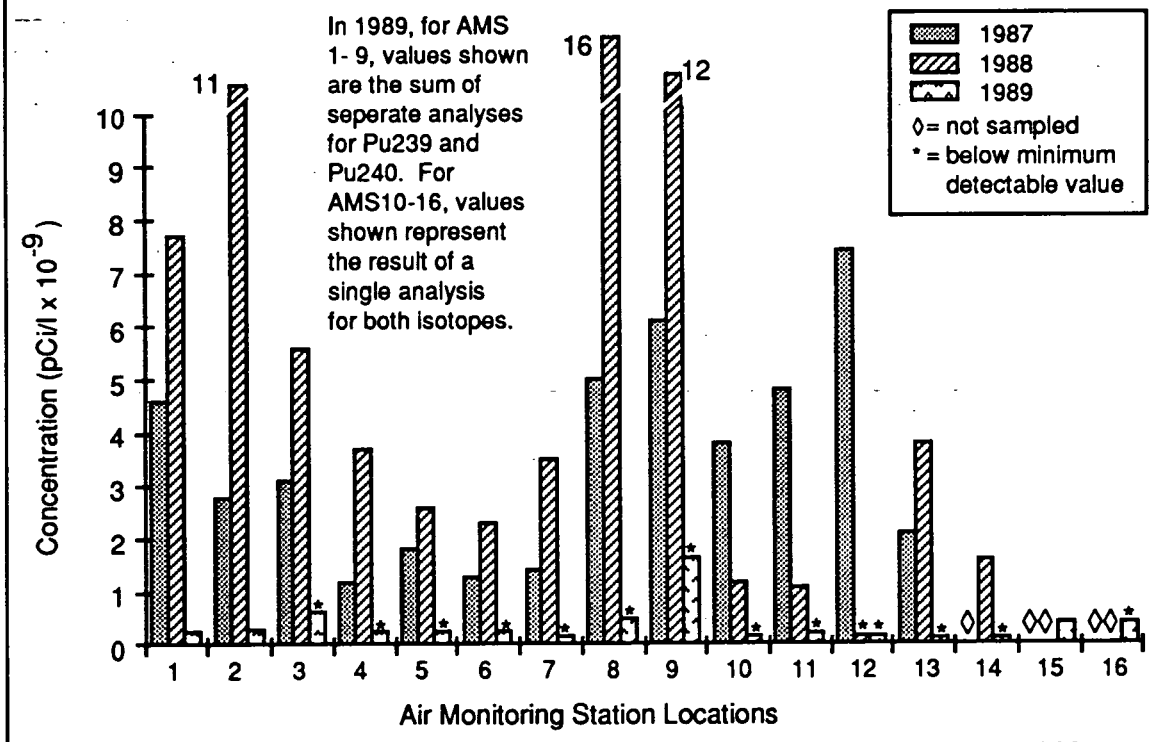


Figure 17. Average Plutonium-239/240 Concentrations in Air, 1987 to 1989

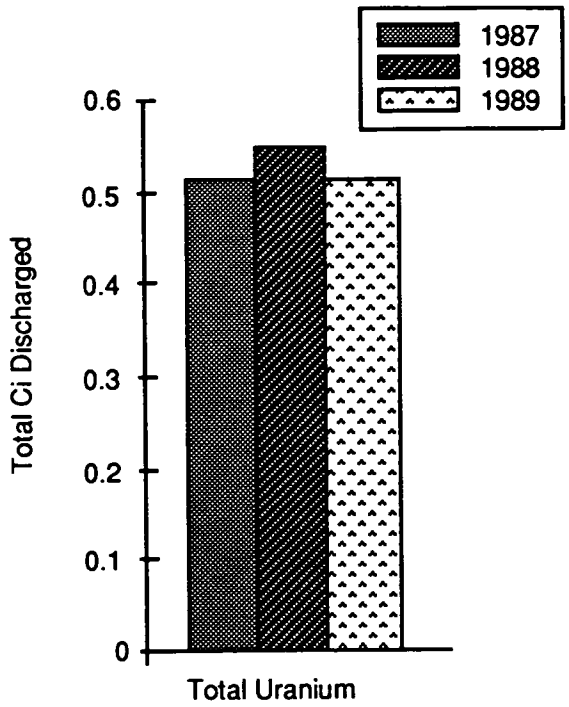


Figure 24. Total Uranium (in Curies) Discharged Through Outfall 001, 1987 to 1989

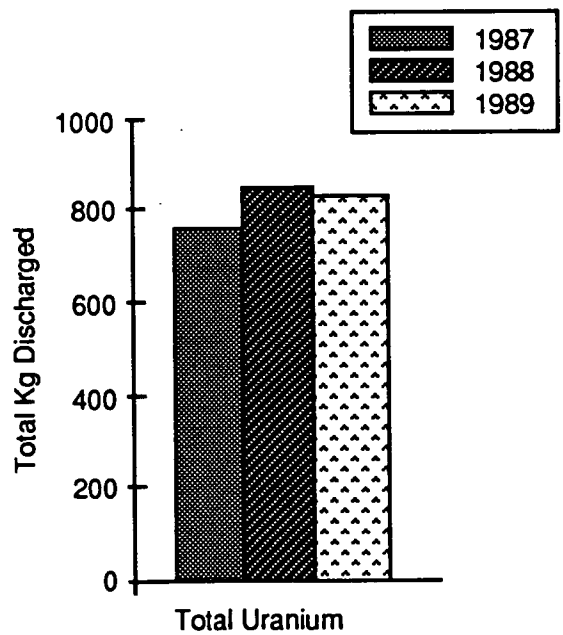


Figure 25. Total Uranium (in Kilograms) Discharged Through Outfall 001, 1987 to 1989

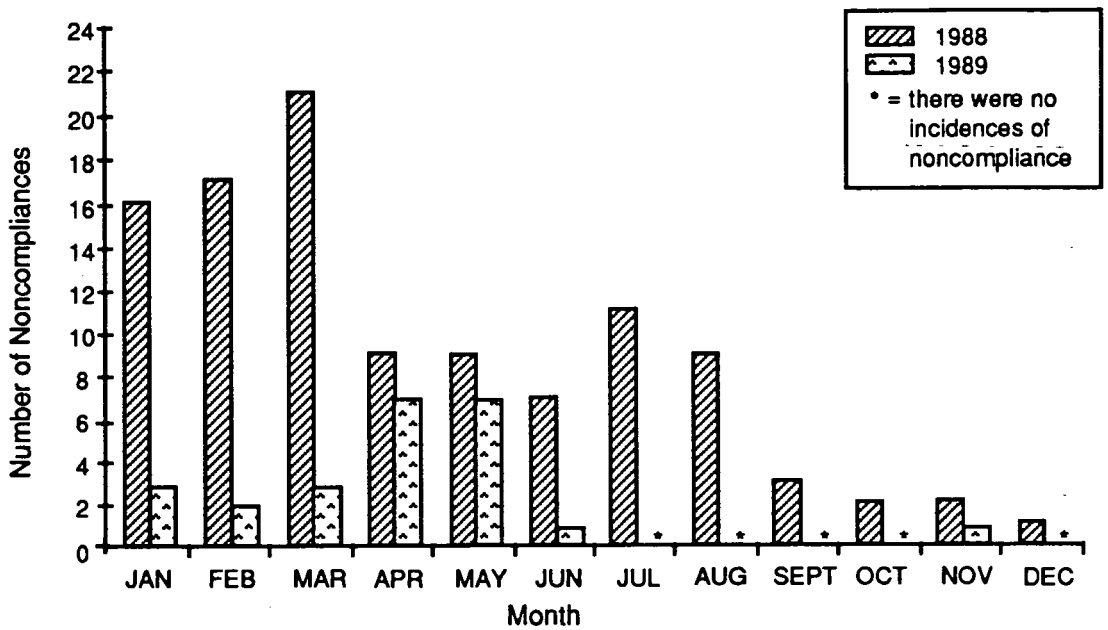


Figure 26. NPDES Noncompliances, 1988 and 1989

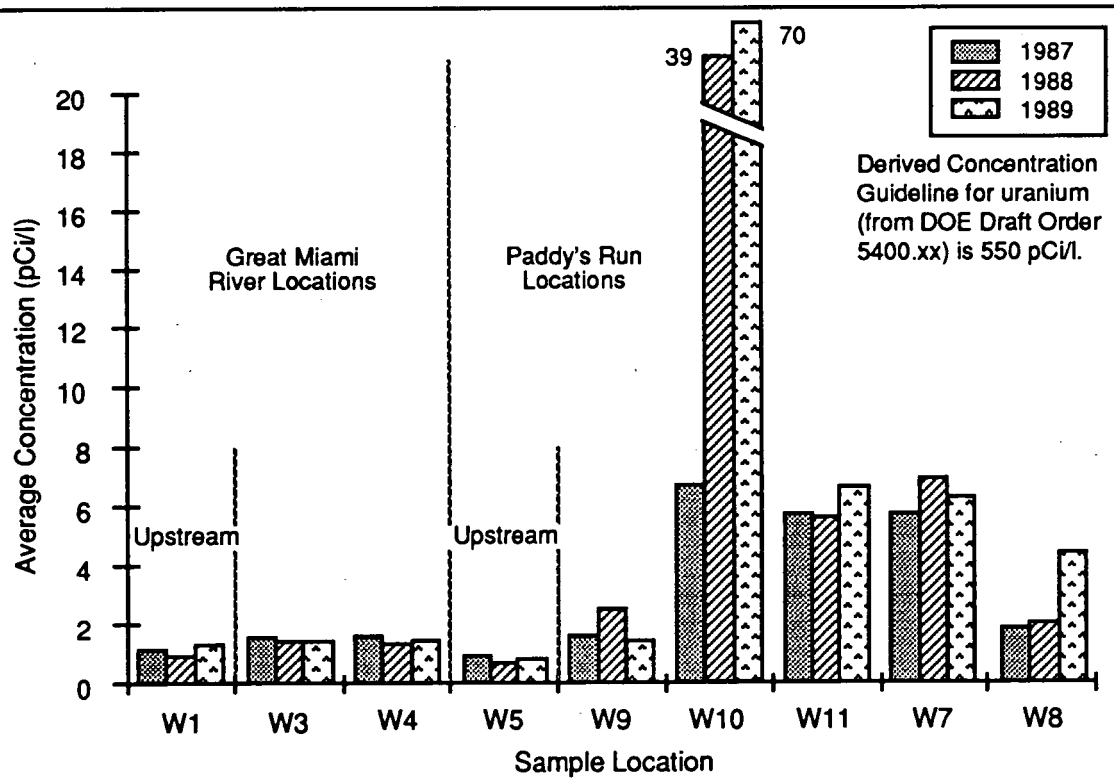


Figure 28. Average Uranium Concentration in Surface Water, 1987 to 1989

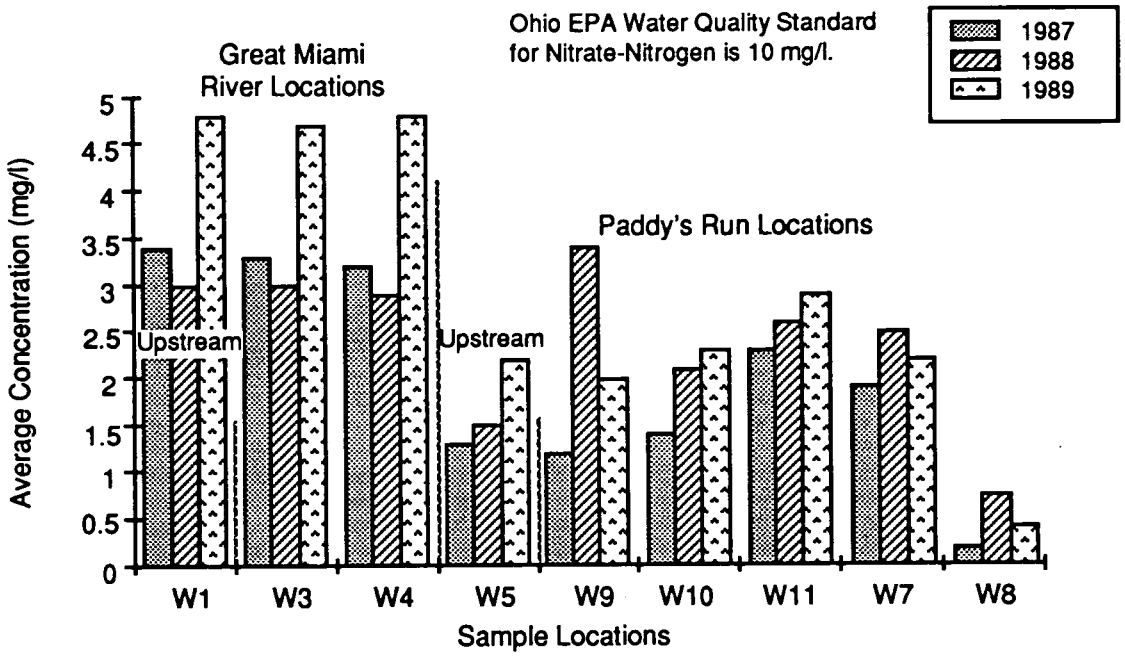


Figure 29. Average Nitrate-Nitrogen Concentration in Surface Water, 1987 to 1989

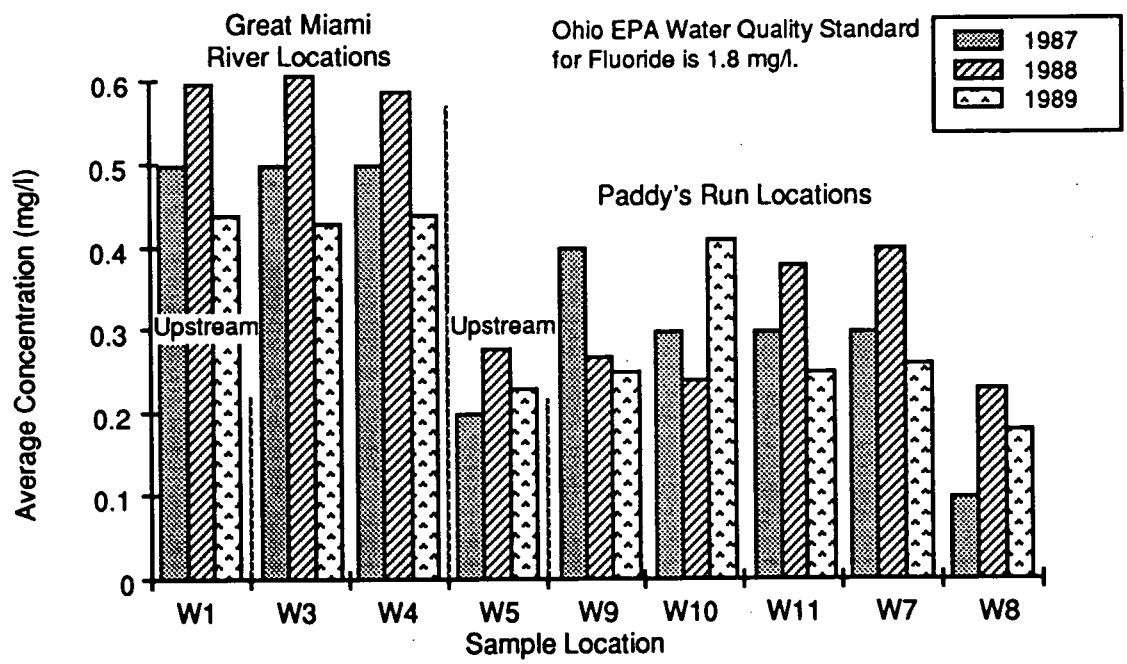


Figure 30. Average Fluoride Concentration in Surface Water, 1987 to 1989

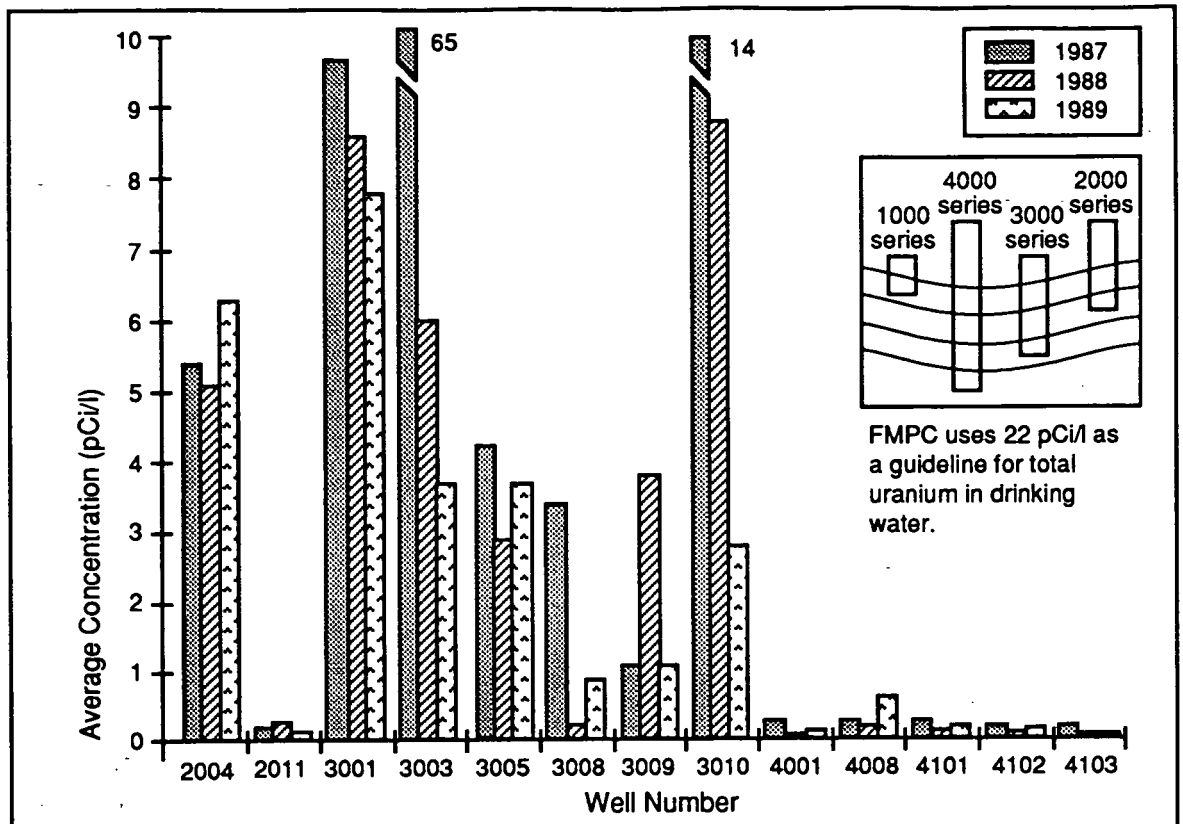


Figure 35. Average Uranium Concentration in Onsite Wells, 1987 to 1989

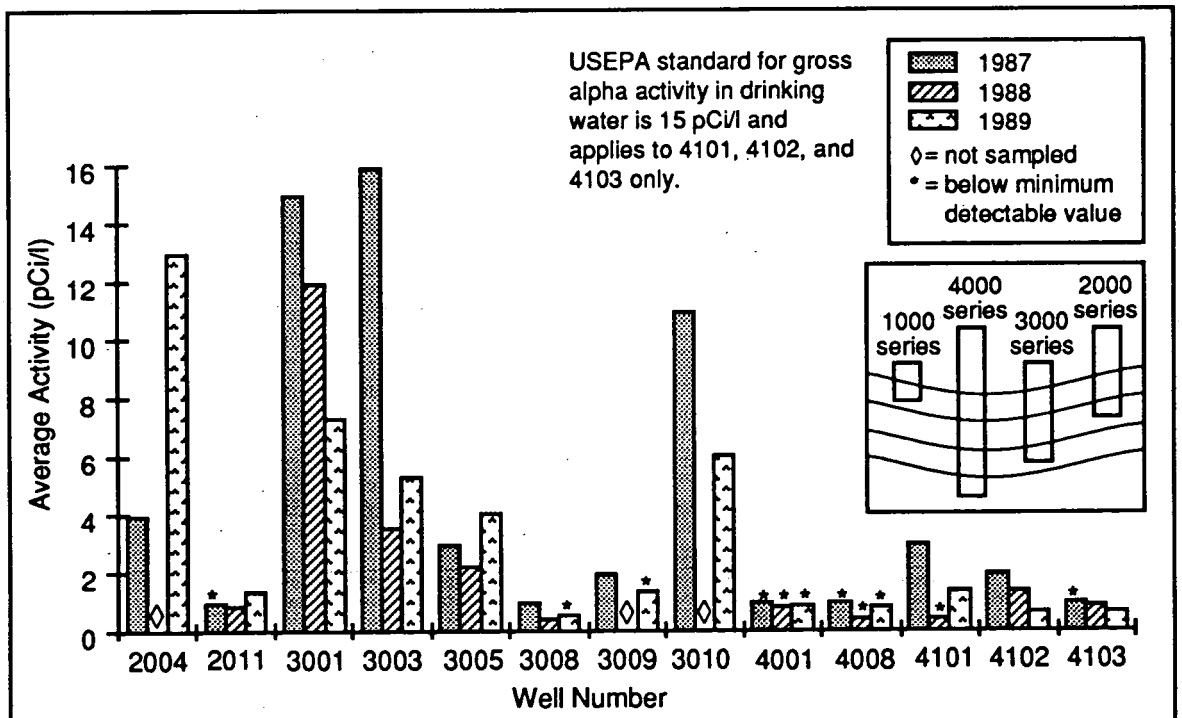


Figure 36. Average Gross Alpha Activity in Onsite Wells, 1987 to 1989

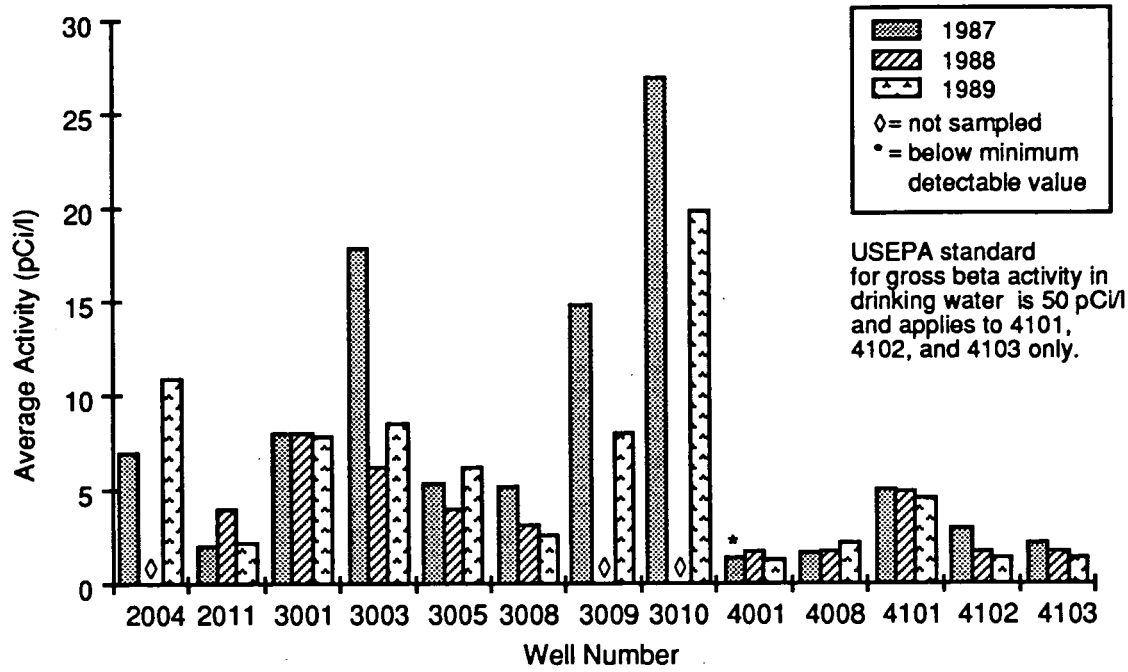


Figure 37. Average Gross Beta Activity in Onsite Wells, 1987 to 1989

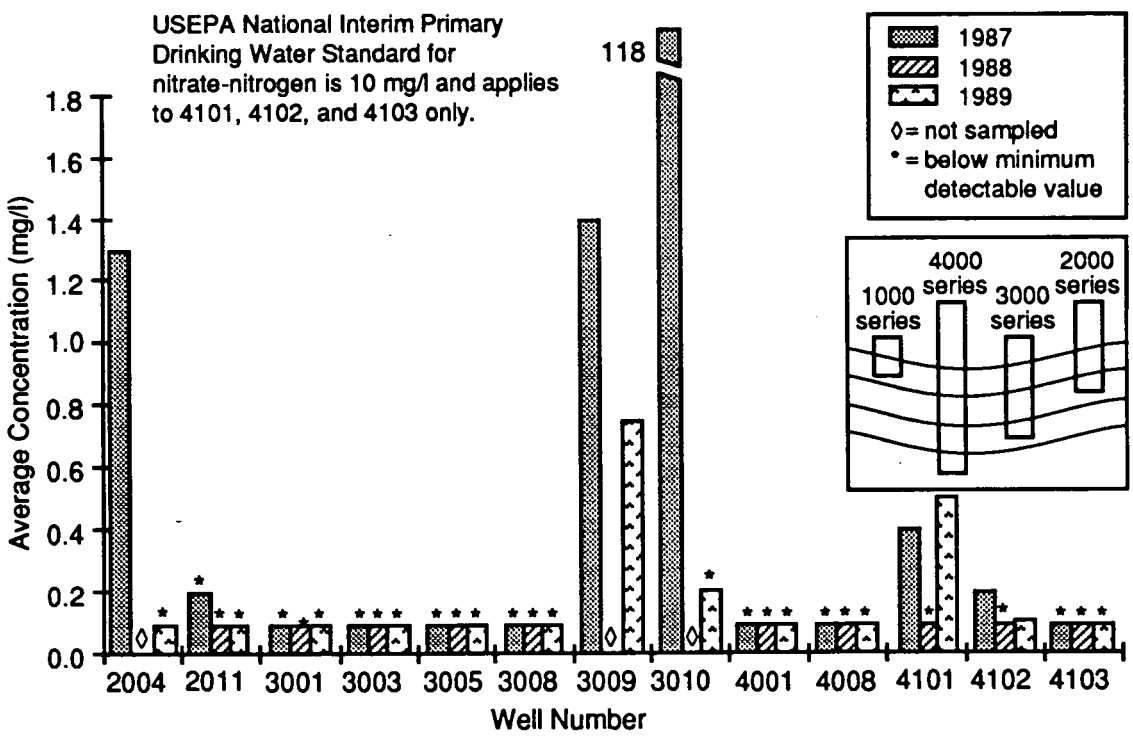


Figure 38. Average Nitrate-Nitrogen Concentrations in Onsite Wells, 1987 to 1989

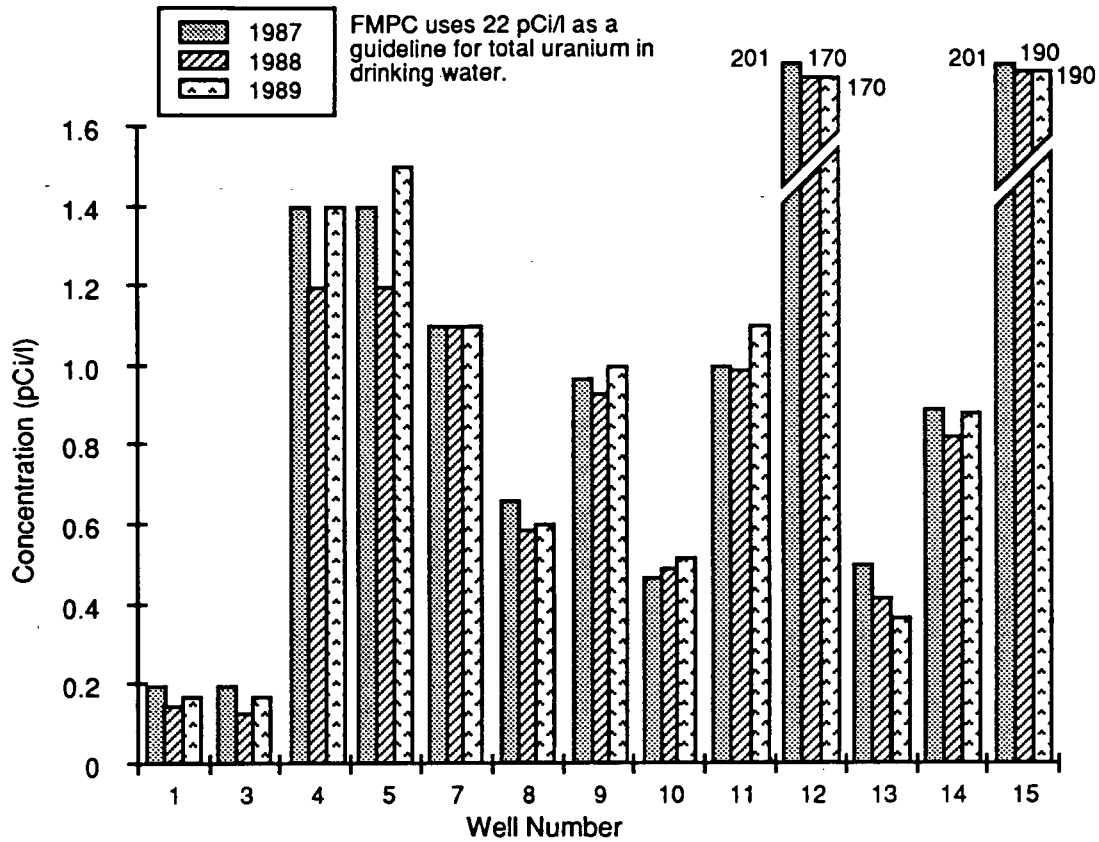


Figure 40. Average Uranium Concentration in Offsite Wells, 1987 to 1989

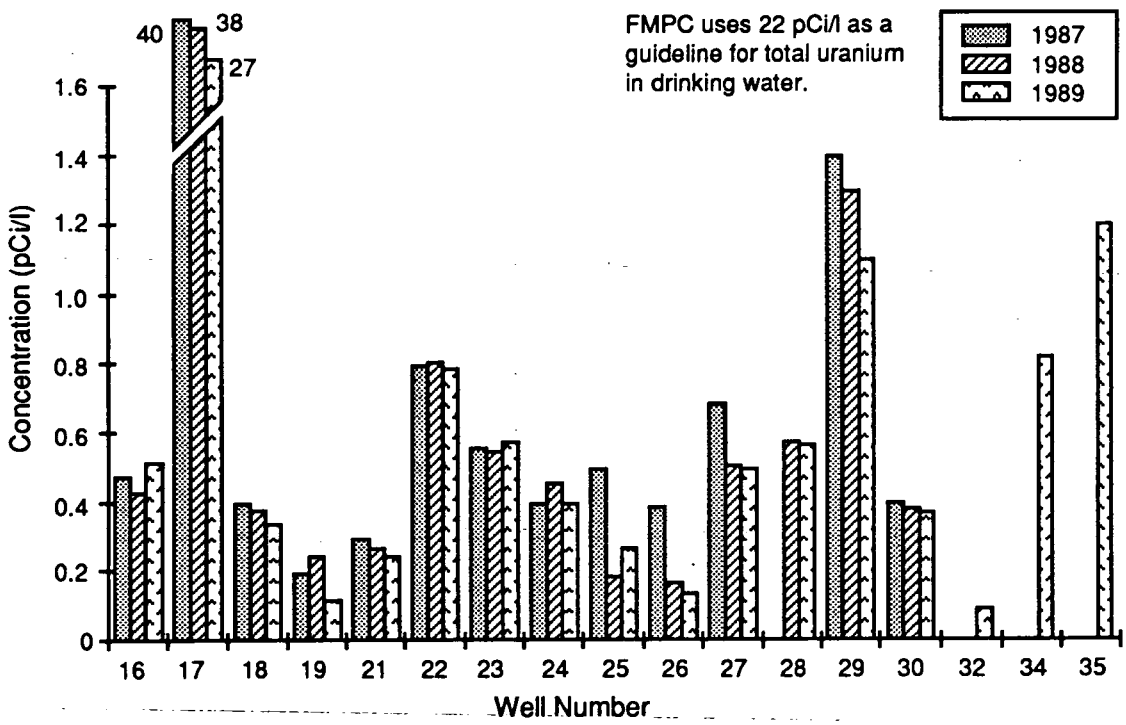


Figure 41. Average Uranium Concentration in Offsite Wells, 1987 to 1989

APPENDIX C

# Chemical Release Information for 1989

Among the information presented in the Environmental Monitoring Annual Report (EMR) for the Feed Materials Production Center (FMPC) are estimates on both radiological and nonradiological emissions to the environment. The information in this appendix includes chemical release estimates from the Superfund Amendments and Reauthorization Act of 1986 (SARA) 313 report for 1989 and a summary of emissions from the FMPC Boiler Plant during 1989.

To estimate releases, the FMPC used a method that followed guidelines defined under SARA 313. These estimates do no reflect actual measured emissions. Indeed, FMPC estimated releases via material balance calculation, monitoring data, or engineering calculations. By following these guidelines, FMPC estimated releases via material balance calculation, monitoring data, or engineering calculations. In cases where quantitative monitoring data, inventory estimates, or emission factors were not readily available, release estimates were based on best engineering judgments. Information obtained from air permits, rate of operation, quantities used, and known treatment efficiencies were used to estimate quantities released into the environment. Typically, assumptions based on best engineering judgement were required in order to perform the calculations when all variables were not know.

Calculations for Boiler Plant emissions were based on published AP-42 emission factors and coal use and analysis records for the FMPC during 1989.

The SARA 313 chemicals included in this addendum are a summary of the SARA Title III, Section 313 report, required by SARA legislation. This report is submitted to the USEPA and OEPA each year on July 1 for the previous calendar year and contains chemicals on the USEPA's toxic substance list. Any listed chemical manufactured in excess of 25,000 pounds, processed in excess of 25,000 pounds, or otherwise used in excess of 10,000 pounds at a facility during 1989 must be reported.

| FMPC CHEMICAL RELEASE INFORMATION FOR 1989 | | | | |
|---|---|---|---|---|
| *Chemical Name* | *Type of Release* | *Quantity Released (lb/kg)* | *Major Release Sources* | *Basis of Estimate* |
| ***Section One: Summary of SARA 313 Report*** | | | | |
| Ammonia | Air: fugitive | 140/64 | Chemical Process | Published Emission Factors |
| Hydrochloric Acid | Air: fugitive | 120/55 | Ancillary Uses[a] | Best Engineering Judgement |
| | Air: point source | 50/22 | Coincidental Manufacturing | Published Emission Factors |
| Methanol | Air: fugitive | 360/160 | Chemical Processing Aid | Published Emission Factors |
| | Air: point source | 260/120 | Chemical Processing Aid | Published Emission Factors |
| | Water: Great Miami River | 23/10 | Chemical Processing Aid | Best Engineering Judgement |
| Nitric Acid | Air: fugitive | 1,200/550 | Chemical Processing | Published Emission Factors |
| Sulfuric Acid | None | N/A | Ancillary Use[b] | Best Engineering Judgement |
| ***Section Two: Boiler Plant Emissions*** | | | | |
| Particulates | Air: stack emissions | 27,900/12,700 | Fossil Fuels Combustion | Stack Testing |
| Sulfur Dioxide | Air: stack emissions | 813,000/369,000 | Fossil Fuels Combustion | AP-42 Emission Factors[c] |
| Nitrogen Oxide | Air: stack emissions | 346,000/157,000 | Fossil Fuels Combustion | AP-42 Emission Factors |
| Carbon Monoxide | Air: stack emissions | 124,000/56,000 | Fossil Fuels Combustion | AP-42 Emission Factors |
| Non-methane Volatile Organic Compounds | Air: stack emissions | 1,730/784 | Fossil Fuels Combustion | AP-42 Emission Factors |

a. Chemical processing aid to decontaminate equipment and materials. The waste HCL is pH neutralized and released to the general sump.

b. Chemical processing aid during pH adjustment and regeneration of ion exchangers.

c. Calculations were based on AP-42 emission factors and 1989 FMPC coal use and analysis records.

APPENDIX D

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(2) **Miami University Department of Zoology,** Biological and Ecological Site Characterization of the Feed Materials Production Center, Oxford, OH, FMPC-Sub-018, January 1990.

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(6) Code of Federal Regulations, Title 40, Parts 61.93 and 61.94, National Emission Standards for Hazardous Air Pollutants, Vol. 50, No. 25, February 1985.

(7) **National Council on Radiation Protection and Measurements,** Ionizing Radiation Exposure of the Population of the United States, NCRP-93, 1987.

(8) **Upton, Arthur C.,** *The Biological Effects of Low-level Ionizing Radiation*, Scientific American, February 1982, pp. 41-49.

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(11) **Kingman, Sharon,** *A Lot of Fuss About a Few Millisieverts*, New Scientist, May 15, 1986.

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(23) Code of Federal Regulations, Title 40, Part 141, National Interim Primary Drinking Water Regulations - Subpart B - Maximum Contaminant Levels, July 1, 1984.

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APPENDIX E

# Glossary of Terms

**Activity** the rate of disintegration, expressed as disintegrations per second (becquerels) or in units of curies (one curie = $3.7 \times 10^{10}$ becquerels).

**Alpha particle** type of particulate radiation (identical to the nucleus of the helium atom) consisting of two protons and two neutrons.

**Aquifer** underground layer of material through which water passes. A saturated permeable geologic unit that can transmit significant quantities of groundwater under ordinary hydraulic gradients.

**ALARA** a phrase and acronym (as low as reasonably achievable) used to describe an approach to radiation exposure and emissions control or management whereby the exposures and resulting doses to the public are maintained as far below the specified limits as economic, technical, and practical considerations will permit.

**Aliquot** the fraction of a field sample taken for complete processing through an analytical procedure (a "laboratory sample" of a field sample).

**Beta particle** type of particulate radiation emitted from the nucleus of an atom that has a mass and charge equal in magnitude to that of the electron.

**Blank** a sample of the carrying agent (gas, liquid, or solid) normally used to selectively measure a material of interest that is subjected to the usual analytical procedures process to establish a baseline or background value. This value is then used to adjust or correct the routine analytical results.

**Calibration** the adjustment of the system and the determination of system accuracy using known sources and instrument measurements. Adjustment of flow, temperature, humidity, or pressure gauges and the determination of system accuracy should be conducted using standard operating procedures and sources that are traceable to the National Institute of Standards and Technology.

**Confidence Coefficient** the chance or probability, usually expressed as a percentage, that a confidence interval includes some defined parameter of a

population. The confidence coefficients usually associated with confidence intervals are 90%, 95%, and 99%. For a given sample size, the width of the confidence interval increases as the confidence coefficient increases.

**Confidence Interval** a value interval that has a designated probability (the confidence coefficient) of including some defined parameter of the population.

**Contamination** any substance or material that is somewhere it is not supposed to be.

**Critical Organ** the human organ or tissue receiving the largest fraction of a specified dose limit.

**Critical Pathway** the specific route of transfer of radionuclides from one environmental component to another that results in the greatest fraction of an applicable dose limit to a population group or an individual's whole body, organ, or tissue.

**Curie (Ci) and Becquerel (Bq)** are units of radioactivity that measure the rate of spontaneous, energy-emitting transformations in the nuclei of atoms. One curie equals 37 billion transformations per second. One becquerel equals one transformation per second. One curie (37 billion Bq) of natural uranium is equivalent to a mass of about 1,500 kilograms
(3,300 lb).

**Daughter** a nucleus that results from radioactive decay. Also, progeny.

**Decay** the disintegration process of an atomic nucleus.

**Derived Concentration Guide** the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (for example, drinking water or breathing the air) that would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye.

**Dose** quantity of radiation absorbed in tissue.

**Effluent Monitoring** the collection and analysis of samples or measurements of liquid, gaseous, or airborne effluents for the purpose of characterizing and quantifying contaminants and process stream characteristics,

assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards.

**Enrichment** a process to increase the percentage of a desired isotope such as uranium - 235.

**Environmental Detection Limit** the lowest concentration at which a radionuclide in an environmental medium can be unambiguously distinguished for a given confidence level using a particular combination of sampling and measurement procedures, sample volume, analytical detection limit, and processing procedure.

**Fugitive Dust** Dust that did not flow through a production stack. This includes materials such as dust from the waste storage areas, administration areas, dust that originated from construction activities.

**Gamma Ray** type of electromagnetic radiation of discreet energy emitted during radioactive decay of many radioactive elements.

**Half Life** the length of time for half the atoms of a given radioactive substance to decay.

**ICRP** International Commission on Radiological Protection is an organization founded in 1928 and whose function is to recommend international standards for radiation protection.

**Ionization** removal of electrons from an atom, such as by means of interaction with radiation.

**Isotope** atoms with the same atomic number but different mass number. Isotopes usually have the same chemical properties, but could have very different radiological properties (such as half-life and type of radiation emitted).

**Less than Detectable** refers to a measurement or calculated concentration that is not statistically different from the associated background or control value at a selected confidence level.

**Lower Limit of Detection** the smallest amount of a contaminant that can be distinguished in a sample by a given measurement procedure at a given confidence level.

**Minimum Detection Level** the minimum amount of the constituent or species of interest that can be observed by an analytical instrument and distinguished from background and instrument noise with a specified degree of probability.

**Mixed Wastes** hazardous waste that has been contaminated with low-level radioactive materials.

**Monitor** 1) to measure certain constituents or parameters in an effluent stream continuously or at a frequency that permits a representative estimate of the amount over a specified interval of time;
2) the instrument or device used in monitoring.

**NCRP** National Council on Radiation Protection and Measurements chartered by U.S. Congress in 1914 and charged with developing radiation protection standards.

**Nuclide** a general term applicable to all atomic forms of the elements, including isotopes.

**Occurrence** any sudden release or sustained deviation from a regulated or planned performance of an operation that has environmental protection and compliance significance.

**Onsite** refers to the area within the boundaries of a facility or site that is or can be controlled with respect to access by the general public.

**Operable Unit** a discrete action that comprises an incremental step toward comprehensively addressing site problems. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action performed over time, or any actions that are concurrent but located in different parts of the site.

**Person-rem** Collective dose to a population group. For example, a dose of one rem to ten people results in a collective dose of ten person-rem.

**Plate Out** a thermal, electrical, chemical, or mechanical action that results in a loss of material by deposition on surfaces.

**Point Source** the single defined point (origin) of a release such as a stack, vent, or pipe.

**Radioactive Material** refers to any material or combination of materials that spontaneously emits ionizing radiation.

**Radioisotope** a radioactive isotope.

**Radionuclide** refers to a radioactive nuclide. There are several hundred known radionuclides, both artificially produced and naturally occurring; radionuclides are characterized by the number of neutrons and protons in an atom's nucleus and their characteristic decay processes.

**Radioactive Emissions** releases of radioactive materials to the environment.

**Random Samples** samples that are obtained in such a manner that all items or members of the lot, or population, have an equal chance of being selected in the sample.

**Remedial Action** an action that is consistent with the final remedy following a formal examination of the nature and extent of the release, or threat of release, assessment of the risk, and selections of the final remedy based on an evaluation of possible alternatives (RI/FS process).

**Removal Action** any necessary action to abate an immediate threat to health and the environment, including actions necessary to monitor, assess, or evaluate the threat.

**Representative Sample** a sample taken to depict the characteristics of a lot or population as accurately and precisely as possible. A representative sample may be a "random sample" or a "stratified sample" depending upon the objective of the sampling and the characteristics of the conceptual population.

**Roentgen (R) and Coulombs per Kilogram (C/kg)** units of exposure to radioactivity. One R equals $2.6 \times 10^{-4}$ C/kg, and is a measure of the ionization in air due to a source of radioactivity.

**Roentgen Equivalent Man (rem) and Sievert (Sv)** units of dose which account for the relative biological damage due to the type of radiation involved. One rem equals 0.01 Sv.

**Sample** 1) a subset or group of objects selected from a larger set, called the population;
2) an extracted portion of a subset of an effluent stream or environmental medium.

**Sampling** the extraction of a prescribed portion of an effluent stream or of an environmental medium for purposes of inspection and/or analysis.

**Sensitivity** the minimum amount of a radionuclide or other material of interest that can repeatedly be detected by an instrument, system, or procedure.

**Site Characterization** designed to provide the information needed to identify site hazards and to select worker protection methods.

**Spiked Sample** a normal sample of material (gas, liquid, or solid) to which a known amount of some substance of interest is added. Spiked samples are used to check on the performance of a routine analysis or the recovery efficiency of an analytical method.

**Tolerance Limits** a particular type of confidence limit used frequently in quality control work, where the limits apply to a percentage of the individual values of the population.

APPENDIX F

# Environmental Monitoring Report Distribution List

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