G-000-105.54

4751

FINAL SAFETY ANALYSIS REPORT FMPC WASTE STORAGE AREA

DAMES & MOORE/NLO
100
REPORT

4751
2117113

FINAL SAFETY ANALYSIS REPORT
FMPC WASTE STORAGE AREA

Dames & Moore
White Plains, NY 10603

0036791

001

4751

Final Safety Analysis Report
FMPC Waste Storage Area

PREPARED FOR:

NLO, Inc.
Cincinnati, Ohio 45239

PREPARED BY:

K. Petschek
L. Skoski
R. Wild

Dames & Moore
20 Haarlem Avenue
White Plains, NY 10603

0036792

002

TABLE OF CONTENTS

Section Page

1.0 INTRODUCTION AND GENERAL DESCRIPTION OF THE PROJECT.....1-1

2.0 SUMMARY OF THE SAFETY ANALYSIS.....2-1
2.1 Radiation Safety.....2-1
2.1.1 Earthquakes.....2-3
2.1.2 Tornadoes.....2-3
2.1.3 Aircraft Crash.....2-4
2.1.4 Other Phenomena.....2-4
2.2 Toxic Materials Safety.....2-4
2.3 Criticality Safety.....2-5
2.4 Fire Safety.....2-5
2.5 Explosion and High Pressure Safety.....2-5
2.6 Natural Phenomena.....2-5
2.7 Operational Accidents.....2-6
2.8 Man-Made Disasters.....2-6

3.0 SITE DESCRIPTION.....3-1
3.1 Physical Characteristics.....3-1
3.1.1 Meteorology.....3-1
3.1.2 Geology and Seismicity.....3-5
3.1.3 Ground Water Hydrology.....3-6
3.1.4 Surface Water Hydrology.....3-9
3.1.5 Off-Site Population Distribution.....3-10
3.1.6 On-Site Population Distribution.....3-11
3.2 Environmental Quality.....3-11
3.2.1 Air.....3-11
3.2.2 Soils and Sediments.....3-18
3.2.3 Ground Water.....3-18
3.2.4 Surface Water.....3-26

4.0 FACILITY AND PROCESS DESCRIPTION.....4-1
4.1 Facilities.....4-1
4.1.1 Dry Waste Pits.....4-1
4.1.2 Wet Waste Pits.....4-4
4.1.3 Storage Tanks.....4-6
4.1.4 Piping and Valves.....4-6
4.1.5 Waste Inventory.....4-7
4.2 Processes.....4-11
4.2.1 Waste Handling.....4-11
4.2.2 Waste Treatment.....4-16
4.3 Protection and Concentration Systems.....4-17
4.3.1 Fire Protection.....4-17
4.3.2 Criticality Control.....4-18
4.3.3 Monitoring Systems.....4-18

5.0 ACCIDENT ANALYSIS.....5-1
5.1 Introduction.....5-1
5.2 Approach.....5-1

0036793

Section Page

5.3 Definition of Potential Accidents and Assignment of Accident Probabilities....5-4
5.3.1 Natural Phenomena....5-4
5.3.1.1 Earthquakes....5-4
5.3.1.2 Tornadoes....5-4
5.3.1.3 Extreme Winds....5-5
5.3.1.4 Floods....5-5
5.3.1.5 Heavy Precipitation....5-6
5.3.1.6 Normal Precipitation....5-7
5.3.2 Operational Accidents....5-8
5.3.2.1 Systems Failure....5-8
5.3.2.2 Procedure Failure....5-10
5.3.3.1 Train Derailments....5-12
5.3.3.2 Airplane Crashes....5-12
5.4 Estimate of Impacts....5-14
5.4.1 Natural Phenomena....5-14
5.4.1.1 Earthquakes....5-14
5.4.1.2 Tornadoes....5-16
5.4.2 Man-Made Disasters....5-16
5.4.2.1 Airplane Crashes....5-16

6.0 QUALITY ASSURANCE....6-1

7.0 CONDUCT OF OPERATIONS....7-1
7.1 Organization....7-1
7.2 Training....7-5
7.3 Inspection and Testing Program....7-7
7.4 Configuration Control....7-9
7.5 Procedures....7-10
7.6 Safety Review System....7-10
7.7 Emergency Planning....7-11
7.8 Recordkeeping and Reporting....7-11

APPENDIX A-Wind Frequencies and Speeds....A-1
APPENDIX B-Method Used for Estimating Contents of Waste Storage Pits....B-1
APPENDIX C-Airborne Suspension of Particulates....C-1
APPENDIX D-Radon Flux Calculation....D-1
APPENDIX E-Dose Calculation Methods....E-1

REFERENCES....R-1

0036794 004

LIST OF FIGURES

Figure		Page
3-1	Area Map Showing Relative Locations of FMPC and Population Centers	3-2
3-2	Wind Direction Frequencies and Speeds-Greater Cincinnati Airport	3-4
3-3	Concentration of Nitrate in Test Well #1-Shallow 1976-1981	3-24
3-4	Concentration of Nitrate in Outfall 1976-1981	3-25
4-1	Waste Treatment and Storage Locations	4-2
4-2	Liquid Waste Flow Diagram	4-15
4-3	Air and Water Sampling Locations	4-20
4-4	Test Well and Production Well Location	4-21
7-1	Transportation Department Organization	7-2
7-2	Water Treatment Plant Organization	7-3

LIST OF TABLES

Table		Page
2-1	Summary of Doses to the Nearest Offsite Resident	2-2
3-1	Known Ground Water Use Within 2 Miles of the Feed Materials Production Center	3-8
3-2	Population Estimates for the 50 Mile Area Surrounding the FMPC	3-12
3-3	Approximate FMPC On-Site Population	3-13
3-4	Concentration of Radioactive Contamination in Air During 1974-1980	3-15
3-5	Concentration of Radon in Air	3-16
3-6	Ambient Air Radon Concentrations Within the K-65 Tank Area Security Fence	3-17
3-7	Uranium in Soil, 1978-1980	3-19
3-8	Typical Ground Water Quality in the Great Miami River Valley Aquifer	3-20
3-9	Concentration of Non-Radioactive Contaminants in Ground Water, 1981	3-22
3-10	Concentration of Radioactive Contaminants in Ground Water, 1981	3-23
3-11	Concentration of Radioactive Contaminants in Surface Water, 1971-1980	3-27
3-12	Concentration of Non-Radioactive Contaminants in Surface Water, 1980	3-29
4-1	Waste Storage Facility Characteristics	4-3
4-2	Estimated Waste Content in Each Pit	4-10
4-3	General Sump Specifications	4-13
5-1	Probability Classification System	5-2
5-2	Hazard Classification System	5-3
5-3	Source Term Summary	5-19
5-4	Accident Probability and Hazard Classification	5-20

1.0 INTRODUCTION AND GENERAL DESCRIPTION OF THE PROJECT

The safety analysis report for the Feed Materials Production Center (FMPC) waste storage area was prepared in compliance with United States Department of Energy (USDOE) Order 5481.1A. As stated in USDOE Order 5481.1A, it is the policy of the United States DOE to assure that their operations are conducted in a manner that will:

- o Limit risks to the health and safety of the public and employees and,
- o Adequately protect property and the environment.

This assurance is provided in part by the preparation and review of safety analyses for DOE operations. The basic responsibility for assuring implementation of this policy lies with the line organization responsible for the operation. The assignment of responsibilities for safety analysis and review tasks delegated to the Oak Ridge Operations Office is set forth in USDOE Order OR 5481.1A. That order also provides guidance on the content and format of safety analysis reports.

The purpose of a safety analysis process is to define and evaluate the parameters of the system and its performance in relation to hazard containment/confinement and risk implications. Part of the process, as outlined in DOE order 5481.1A, requires: (1) systematic identication of all potential hazards under all conceivable scenarios, (2) accurate analysis of potential impacts, (3) discussion of measures taken to eliminate, control or mitigate the hazards. This analysis complies with these requirements.

The system of concern in this report is the waste storage facility area of the Feed Materials Production Center (FMPC) located in southwestern Ohio. The FMPC is operated by NLO, Inc. under contract to the USDOE, Oak Ridge Operations Office. The FMPC has been storing its wastes in this area since 1952.

0036797

007

The primary work at the FMPC is the production of purified uranium metal and compounds for use at other DOE sites. The uranium may be depleted, normal or slightly enriched, however, the average is close to normal. Through 1976, the plant's major starting material was semi-pure uranium concentrate and most of the waste stored or disposed of at the site resulted from conversion of this material to UO_3 or reactor grade uranium metal.

The characteristics of the site are discussed in Chapter 3 of this document, and the waste storage facilities are described in detail in Chapter 4. The results of the analysis of probabilities and impacts of postulated accidents are presented in Chapter 5. Quality assurance is discussed in Chapter 6. An overview of how management conducts operations to insure safety and assure that the staff is technically competent and safety oriented is presented in Chapter 7. The results of the safety analysis are summarized in Chapter 2.

2.0 SUMMARY OF THE SAFETY ANALYSIS

2.1 Radiation Safety

The feasibility and evaluation of a number of natural and manmade events were investigated to determine their effect on the FMPC waste storage area and the potential radiological consequences resulting therefrom. These included:

- o Earthquakes
- o Tornadoes
- o Extreme Winds
- o Floods
- o Precipitation (heavy and normal)
- o Systems Failures
- o Procedure Failures
- o Train Derailments
- o Aircraft Crashes

Results of the analysis negated the possibility for any major consequence to occur due to the majority of these events. Where consequences were potentially significant due to dispersion of radiological material, the probability of occurrence was small. The following briefly reviews and summarizes these incidents. The dose to the nearest individual is summarized in Table 2-1.

The radionuclides encountered in the waste stored at the site and therefore included in the source term calculations are uranium, thorium, radium, and daughters. The estimated total curies in each of the site facilities are as follows:

Facility	Curies
Pit 1	108
Pit 2	35
Pit 3	553
Pit 4	233
Pit 5	327
Pit 6	178
Metal Oxide Tank	23
K-65 Tanks	17,600

0036800

TABLE 2-1

Summary of Doses to the Nearest Offsite Resident
(mrem)

Initiating Event	Radionuclides		WB	Bone	Liver	Thyroid	Kidney	Lung	GI
Earthquake Rupture of K-65 tank	Ra-226	Organ Dose	9.5E-02	1.5E-01	4.1E-03	-	1.3E-02	5.4E-02	1.1E-(
	Rn-222	Organ	-	-	-	-	-	Lung	-
		Dose	-	-	-	-	-	2.1E-04	-
Aircraft striking the K-65 tank	Ra-226	Organ Dose	2.9E+01	4.1E+01	1.7E-04	1.7E-04	1.7E-04	1.5E+01	3.5E-(
	Rn-222	Organ	-	-	-	-	-	Lung	-
		Dose	-	-	-	-	-	8.2E+02	-

010

4251

Pits 1, 2, 4 and 6 are considered dry waste pits. They contain waste such as filter cakes, graphite, brick, raffinate, non-burnable trash and some slurries. Pits 4 and 6 are open while 1 and 2 are closed. Pits 3 and 5 are wet waste pits. These pits have functioned as settling basins for liquid process waste streams and therefore contain liquid and precipitated material. Pit 5 is open whereas Pit 3 is closed. The metal oxide tank contains residues bearing a trace of radium from processing of non-pitchblende ore concentrates. The K-65 tanks contain radium bearing residues from pitchblende ore processing. Most of the waste in the tanks is a wet claylike material, however, a layer approximately one foot deep at the top is dry. All the wastes are neutralized before disposal rendering them chemically inert and virtually insoluble.

2.1.1 Earthquakes

The probability of a major earthquake (modified Mercalli VIII or IV) during the assumed plant life time of 40 years is of the order of 10^{-4}. The major radiological impact of such a seismic event would be a rupture of the K-65 tank and subsequent release of the stored waste. The released material is assumed to spread out over an area of the embankment and for the period before cleanup (1 month) acts as a source of airborne particles and radon gas. This gives rise to source terms of 142 pCi/sec for radium contaminated particulates and 7.3×10^{2} pCi/sec for radon gas.

The resulting maximum radiological impact to nearest resident is 0.15 mrem to the bone due to Ra-226. Other doses are equally negligible and are presented in Table 2-1.

2.1.2 Tornadoes

The probability of a tornado impinging on the waste storage area has been calculated as 2.5×10^{-5} per year. The major radiological consequence of this event is the potential for airborne dispersion of

a portion of the pit wastes. An analysis of this dispersion leads to the conclusion that the amount and area over which this dispersion may occur will have a negligable impact on the area in question and result in negligible doses.

2.1.3 Aircraft Crash

While the probability of this event occuring is extremely low (of the order of 10^{-9}), the radiological impact is the most significant of those discussed. The release of particulate matter and the radon "puff" from the assumed 30 minute event results in source terms of 1.1×10^{6} pCi/sec for radium contaminated waste and 1.7×10^{10} pCi/sec for radon. This leads to a maximum nearest resident dose of 29 mrem to the whole body, 41 mrem to the bone and a lung dose of 820 mrem.

As expected, the lung dose is the only significant impact. This is primarily due to the extremely high concentration of radium-226 and radon-222 in the material, the radon emanation coefficient chosen for this analysis, and the conservative approach used in the scenario.

2.1.4 Other Phemonena

The topography of the waste storage area, the inability of the Paddy's Run and the Miami River to flood the site, the design of the pits and dike system, and the operation of the site negate any radiological consequences due to extreme winds, precipitation (heavy or normal), system or procedure failures and train derailments. These are discussed in detail in Section 5.0.

2.2 Toxic Materials Safety

Toxic chemicals used in processes carried out at the FMPC include anhydrous ammonia, hydroflouric acid, hydrochloric acid, and nitric acid. As acids, these chemicals are irritants to the eyes,

mucous membranes and skin, however, since they are neutralized to a pH of 9.0 prior to discharge from the General Sump, they present no safety hazard in the waste storage area.

2.3 Criticality Safety

The materials discarded to the waste storage area are depleted so far below normal enrichment levels (<0.4%), that criticality can not occur.

2.4 Fire Safety

Only minimal amounts of pyrophoric materials are transferred to the waste storage area. These materials are primarily magnesium and uranium particles. The quantities are very small and therefore not considered a fire hazard. Fire prevention inspections of the site are made on a monthly basis. In the event that a fire should occur, the waste storage area is equipped with two dry chemical fire extinguishers, a hose, and a manual fire alarm box. In addition, a well-equipped fire brigade is available with response capabilities 24 hours a day.

2.5 Explosion and High Pressure Safety

The lack of a fire hazard and the absence of pressurized vessels or conduits in the waste storage area preclude explosion or high pressure hazards at the site.

2.6 Natural Phenomena

Review of seismological, meteorological, and hydrological data for the region surrounding the site show that natural phenomena are not a source of significant risk. Past earthquakes which have occurred in the region have been of low intensity. Meteorological phenomena have also been shown not to be of a significant risk.

2.7 Operational Accidents

As discussed in Section 5, a number of system and procedure failures would have to occur simultaneously in order for any accident consequence to occur. In any event, the results are shown to be neglible.

2.8 Man-Made Disasters

The only man-made disaster of consequence is the aircraft accident scenario the impact of which is presented in Section 2.1.

3.0 SITE DESCRIPTION

The Feed Materials Production Center (FMPC) is located in a rural area of southwestern Ohio approximately 10 miles northwest of Cincinnati and 8 miles southwest of Hamilton (Figure 3-1). The facility occupies 136 acres in the center of a 1,050 acre site. Most of the site, including all of the production and waste storage area, is in Hamilton County. Approximately 200 acres are in Butler County.

The site is bounded on the west by Paddy's Run Road, on the south by Willey Road, on the north by farm land and State Route 126 and on the east by a dairy farm. The villages of Fernald, New Baltimore, Ross and Shandon are all located within five miles of the plant. Farming is the major industry surrounding the FMPC plant while manufacturing is the major industry in the surrounding region.

The waste storage facilities which consist of six waste storage pits, two concrete silos (the "K-65 tanks") and two metal oxide tanks are located in an area on the west side of the plant about 900 feet from the site boundary. The waste storage area occupies approximately 37.7 acres. The area is relatively flat with some sloping due to the final soil covering over buried wastes. Paddy's Run, an intermittent tributary of the Great Miami River, runs along the west side of the project between the waste area and the site boundary.

3.1 Physical Characteristics

3.1.1 Meteorology

Meteorological data such as precipitation, wind speed and direction was routinely collected at the site during the period 1960 through 1979. This data has been augmented with data from Greater Cincinnati Airport 17 miles to the south and weather observation stations in Hamilton 8 miles to the northeast.

4751

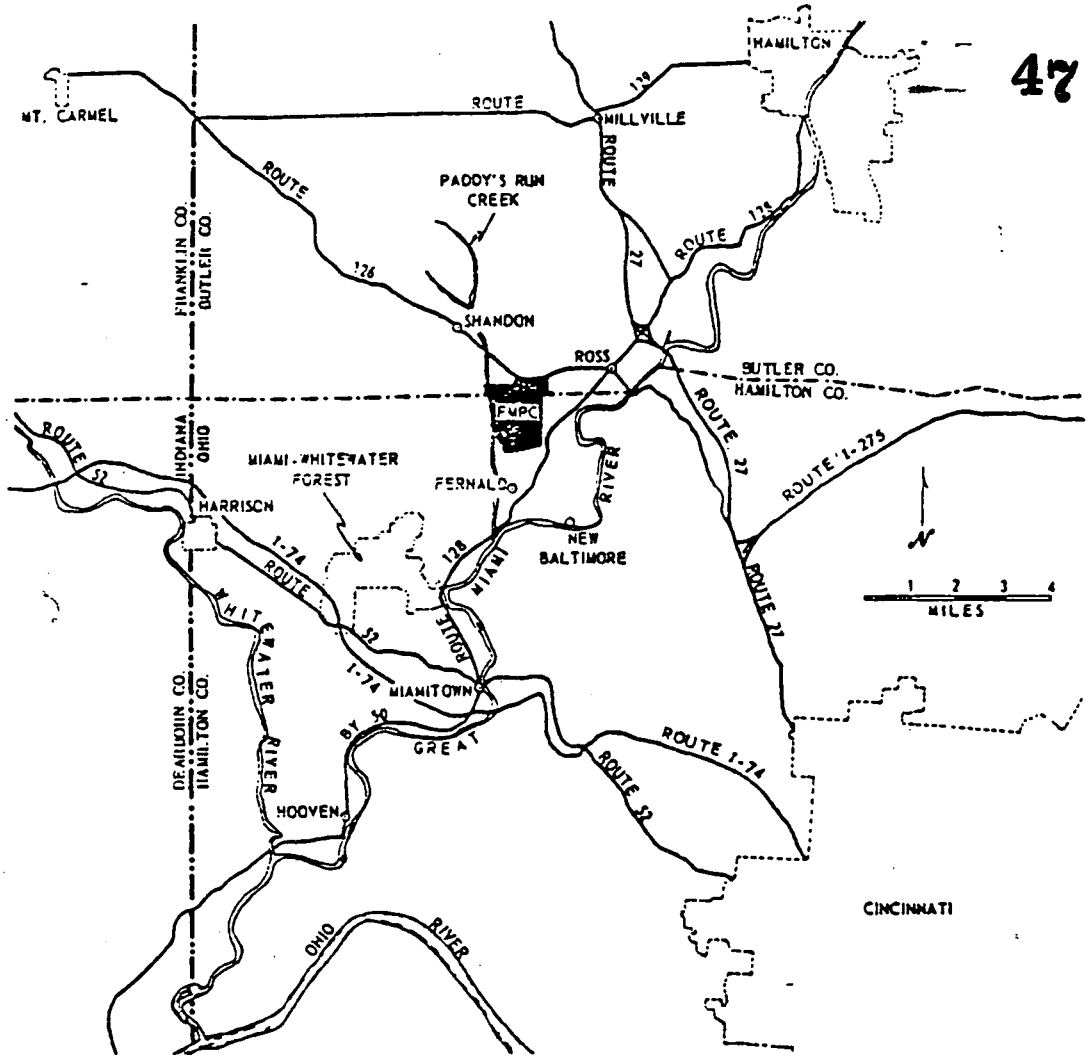


FIGURE 3-1
AREA MAP SHOWING RELATIVE LOCATIONS OF FMPC AND POPULATION CENTERS

0036806

DAMES & MOORE

016

REVISIONS BY ____ DATE ____

FILE ____

BY ____ DATE ____

CHECKED BY ____

Winds

The prevailing wind direction is from the south-southwest at a mean speed of 9.1 mph. Figure 3-2 presents a wind rose showing the wind direction frequencies over the period 1970-1974 at the Greater Cincinnati Airport (Ref. 1). Detailed recent information on wind speeds, directions and stability classes are presented in Appendix A.

The maximum wind velocity recorded at the airport was 40 mph from the SSW and was observed 5 times in a 12 year period ending in 1973 (Ref. 2). Wind records from the site list gusts in excess of 50 mph on 11 occasions during the period 1960-1976 while on two occasions the wind speed exceeded 60 mph (Ref. 2).

Tornadoes

Ohio lies on the eastern edge of an area of maximum tornado frequency, the centerline of which extends from northern Texas to southwestern Ohio. During the period from 1953 to 1972, 235 tornadoes struck Ohio. Over the period 1900-1978, 15 tornadoes were observed in Hamilton County. Only one tornado, causing no damage, is known to have reached the site; this occurred May 10, 1969. Another tornado passed near the northeast boundary on May 13, 1973 but also caused no damage to the site (Ref. 2).

Precipitation

The measured average annual precipitation for the period 1960 to 1979 was 37.75 inches, ranging from 29.22 to 47.72 inches. Monthly extremes ranged from 0.04 inches to a maximum of 11.15 inches. In March of 1964, an extreme maximum 24 hour rainfall of 5.21 inches was measured at the Greater Cincinnati Airport.

REVISIONS
BY DATE
FILE
CHECKED BY DATE

4751

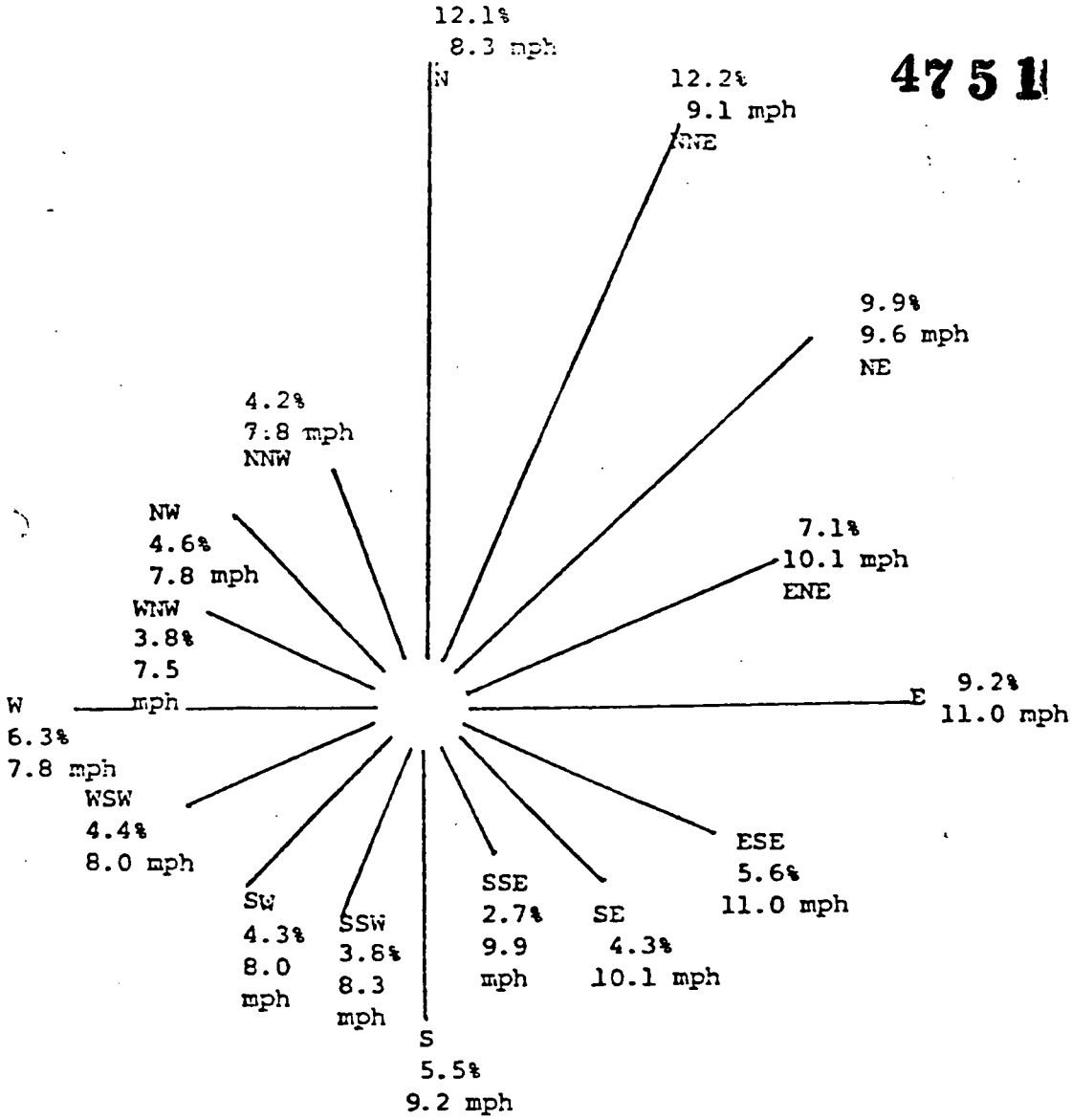


FIGURE 3-2
WIND DIRECTION FREQUENCIES
AND SPEEDS-GREATER
CINCINNATI AIRPORT

0036808

DAMES & MOORE
018

Annual snowfall at Hamilton averaged 15.3 inches over a 29 year period. The maximum in a 24 hour period was 9.8 inches (Ref. 2).

3.1.2 Geology and Seismicity

The site is located in a 3 mile wide glacial valley branching westward from the Great Miami River valley between Ross and Hooven, Ohio. The valley is an abandoned course of the Ohio River which carved a deep bedrock trough during the Deep Stage Interglacial Period. The New Haven Trough, as it is called, was subsequently filled to a depth of about 200 feet with glacial outwash and drift deposits from recession of the Illinoian and Wisconsin ice sheets. The floor of the bedrock trough, which lies at an elevation of about 350 feet above mean sea level (msl), consists of limestone and shale strata of Upper Ordovician age. Beyond the boundaries of the glacial valley, these indurated sedimentary rocks form rolling hills having a maximum elevation of 875 feet msl. The site itself lies on top of the New Haven Trough, at an elevation of about 580 feet msl.

The Pleistocene glacial deposits beneath the site consist of clay till overlying a highly permeable sand and gravel aquifer that extends to bedrock. The drilling records of test wells installed in the waste storage area show that the glacial till consists of blue or yellow clay 40 to 50 feet thick; below the upper 10 feet it often contains lenses and pockets of sand or gravel (Ref. 3). At the base of the till, at an elevation of about 540 feet, there is a sharp transition to sand and gravel outwash deposits. These vary in texture laterally and vertically, containing more or less gravel and lenses of poorly graded fine to medium sand. At an elevation of about 450 feet msl, there is a laterally continuous lens of blue clay. This clay stratum is 10 to 15 feet thick and separates the aquifer into upper and lower segments.

0036809

The site and surrounding area (southwest Ohio) is included in a seismic category 2 on the U.S. Geological Survey's Seismic Risk Map. This category defines an area where "moderate" earthquake damage is expected to occur. During the period 1976-1980, approximately 80 earthquakes were recorded in Ohio. Of these, six seismic events of low intensity (III on the Modified Mercalli Intensity (MMI) Scale, 1956 revision) occurred in the Cincinnati area. A significant seismic event occurred at Sharpsbury, Kentucky (on July 27, 1980 - resulting in a MMI of VII at the epicenter and IV at the site. Seismic events frequently occur at Anna, Ohio (Modified Mercalli - VII and VIII) more than 60 miles northeast of the site. These shocks have caused toppled chimneys and cracked walls. The Sharpsbury, Kentucky event toppled chimneys in the Cincinnati area. In both cases no damage occurred at the site (Ref. 2).

3.1.3 Ground Water Hydrology

The thick sand and gravel glacial outwash deposits filling the Great Miami Valley glacial trough form a valuable ground water resource in southwestern Ohio (Ref. 4). In many places the aquifer is 150 to 200 feet thick and yields more than 1,000 gallons per minute (gpm) to individual wells. The regional yield is limited mainly by the availability of recharge from precipitation or surface water sources, in particular the Great Miami River. The aquifer yields are highest and most reliable in areas where a high saturated thickness of sand and gravel is accompanied by recharge from the river, unimpeded by overlying glacial till layers such as those that occur at the waste storage site. Extremely high aquifer yields occur to the south and east of the site where the Great Miami River has eroded the surficial clay deposits allowing free recharge to the aquifer.

The overlying clay till layer is expected to have a relatively low permeability, restricting transport of contaminants from the ground surface to the aquifer. In contrast, the permeability of the sand and gravel is extremely high; an aquifer pumping test conducted

in 1962 at the site indicated that the transmissivity of the lower aquifer is approximately 150,000 gallons per day per foot (gpd/ft) (Ref. 4). Assuming the permeability of the upper aquifer is similar, the transmissivity of the two segments combined is estimated to be on the order of 300,000 gpd/ft.

The alluvial aquifer is used for both domestic and industrial water supply in this area. Review of water well logs on file with the Ohio Department of Natural Resources, Division of Water revealed that high yield production wells have been installed by a number of industrial concerns in the village of Fernald 1.5 miles south of the plant as shown on Table 3-1. In addition the Southwestern Ohio Water Company operates two Ranney Collector Wells 1.5 miles east of the site adjacent to the Great Miami River. A pumping rate of 13-15 million gallons per day (mgd) was reported in 1964 and is expected to have increased since (Ref. 4). This level of pumping induces extensive infiltration of water from the Great Miami River into the aquifer. Farms and residences in the area (there are 25 within one mile of the plant) also draw upon this aquifer with small diameter private wells.

At the site, the aquifer is divided into upper and lower segments by a continuous layer of blue clay. The effect of this aquitard layer is apparent in two pairs of test wells installed in the waste storage area. One of each pair of wells is completed in the upper aquifer and the other is completed in the lower. Water level measurements in these wells show that there is often a difference in hydrostatic head of 1 to 2 feet between the two aquifers usually with a downward hydraulic gradient across the aquitard layer.

The lower segment of the aquifer is used as a water supply by FMPC. About 2000 feet southeast of the waste storage area, three production water wells were drilled in 1951 to a depth of 210 feet. These wells are screened in the lower 20 feet of the aquifer between approximately 370 and 390 feet msl; this is about 50 feet below the blue clay aquitard, and 20 feet above the elevation at which gray

TABLE 3-1

Known[a] Ground Water Use Within 2 Miles of the Feed Materials Production Center

Name and Mailing Address of Well Owner	Well Type	Pump Capacity or Test Rate (gpm)	Probable Water Use	Distance and Direction from site
Strickers Grove 1354 Compton Road Cincinnati, OH	6-inch (2 wells)	100 each well	Domestic	1.4 miles east-southeast
Virginia-Carolina Chemical Co. P.O. Box 11065 Fernald, OH	12-inch	225	Industrial	1.8 miles south
Web Pallet and Box Co. Fernald, OH	8-inch (2 wells)	800 600	Industrial	1.8 miles south
Mobil Chemical Corp. Paddy's Run Road Fernald, OH	12-inch (2 wells)	225 each well	Industrial	1.7 miles south
Harry Klekamp 8001 Hamilton Ave. Cincinnati, OH	8-inch (2-wells)	300 250	Domestic	1.4 miles southeast
Southwestern Ohio Water Co.[b] 11599 E. Miami River Road Ross, OH	Ranney Collector (2 wells)	10,000[c] combined	Domestic & Industrial	1.5 miles east

[a]Well logs on file with Ohio Department of Natural Resources, Division of Water.
[b]No well logs on file. Wells reported in Reference 4.
[c]Estimate based on 13-15 mgd pumpage reported in Reference 4.

shale bedrock was reported in a soil test boring 1600 feet to the east. Approximately 320,000 gallons per day is pumped from Production Water Well No. 3 with Well Nos. 1 and 2 being used only in the case of breakdown.

The depth to ground water beneath the waste storage area varies from 30 to 60 feet depending on the surface elevation. The elevation of the piezometric surfaces for both the upper and lower aquifers fluctuates seasonally from 520 to 525 msl according to measurements made by NLO in eight test wells; however, precision of the ground water level elevation data was not adequate to reliably plot the piezometric surface of either aquifer (Ref. 4). The piezometric elevation measurements in the production water wells vary from 515 to 527 feet msl. These piezometric elevation data indicate that the ground water table lies about 20 to 25 feet below the base of the lowest waste storage pit.

In the absence of accurate ground water elevation data, it is not possible to predict the hydraulic gradient or the direction of ground water flow in the upper and lower segments of the glacio-fluvial aquifer. Pumping from FMPC Production Water Wells is expected to induce an easterly hydraulic gradient, affecting flow of ground water in the lower aquifer in the vicinity of the Waste Storage Area. Pumping from the Southwestern Ohio Water Company wells may also cause an easterly flow in the aquifer at the site. The local hydraulic gradient or direction of flow in the upper aquifer cannot be predicted from the data currently available.

3.1.4 Surface Water Hydrology

The site is located within the Great Miami River Watershed. Natural drainage of the site is to Paddy's Run, a tributary of the Great Miami River, located just west of the waste storage area. The storage area is slightly higher than the land to the east, south, or

west. Drainage from the north is intercepted by a ditch which discharges into Paddy's Run. Surface drainage, therefore, is away from the stored wastes, thus reducing the amount of surface water available for infiltration into the waste. In addition, retired pits are graded in a manner to enhance drainage of precipitation and avoid ponding.

Paddy's Run originates near the plant and flows south on the west side of the waste storage area. Flow in this stream is generally intermittent and is sustained only during the period from January to May, ranging from 0.2 to 4.0 cubic feet per second (cfs) (Ref. 5). The balance of the year it may be considered a dry bed stream with occasional flash flows of a few hours duration following heavy rains. The Great Miami River has a drainage area of 3630 square miles. In 1980, the average flow of the Miami River was 2676 million gallons per day.

Although Paddy's Run has overflown its banks on numerous occasions, it is far enough below the general site level that flooding was inconsequential . In addition, a dike about 10 feet high has been constructed just east of Paddy's Run along its course to further reduce the probability of flood water reaching the waste storage area. Similiarly, flooding of the Miami River does not reach the waste storage site. The approximate elevation of the site is 580 feet (msl) and the Miami River has never been reported over 555 feet at maximum flood stage in this area.

3.1.5 Off-Site Population Distribution

The site is located in a rural area approximately 20 miles northwest of downtown Cincinnati. It is surrounded by land which is primarily used for agriculture. There are approximately 35 residences near the north side; the majority of these in a subdivision to the northeast. There are ten residences and one small business scattered in the remaining adjacent areas. A trailer park is located about 1 1/2 miles southeast of the waste storage area. Fernald and New Baltimore in Hamilton County and Shandon and Ross in Butler County are the communities closest to the plant site (Figure 3-1). A total of

11,350 persons are estimated to live within 5 miles of the plant and 2,577,488 persons are estimated to live within 50 miles of the plant. Table 3-2 shows the population estimates for the surrounding 50 mile area (Ref. 6).

4751

3.1.6 On-Site Population Distribution

The number of people on-site ranges from a minimum of approximately 10 on the third shift on weekends to about 550 on the first shift on weekdays. Table 3-3 gives the number of people working in each area of the facility on each shift. The unassigned first shift category includes 71 mechanical shop employees, 13 transportation department employees, and 1 porter who could be anywhere on the site, as well as roughly 3 guards on patrol. On the second and third shifts there are a similar number of guards. The production plants operate 10 days on and 4 days off, therefore, on half the weekends Plants 1-9 and the Pilot Plant are empty while the other half they are staffed the same as weekdays.

3.2 Environmental Quality

This section presents data from the FMPC environmental monitoring program and serves a dual purpose. In general, the data allows baseline concentrations of chemical and radioactive species to be determined so that the impact of accidental releases can be more accurately assessed. In a few cases the data suggests that releases may have occurred as the result of the failure of containment systems within the Waste Storage Areas. Within the context of this report, any such failures are considered to be safety-related.

3.2.1 Air

The operations at the FMPC which convert impure uranium and thorium compounds to reactor-grade feed materials generate radioactive dust. Weekly particulate samples collected continuously by seven

0036815

025

0036816

TABLE 3-2

Population Estimates for the 50 Mile Area Surrounding the FMPC

Miles From Plant	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Distance Totals	Cumulative Distance Totals
0-1	13	3	6	3	0	6	6	0	10	16	6	3	0	3	0	13	88	88
1-2	13	10	323	134	19	3	493	13	38	42	48	6	10	10	22	29	1,213	1,301
2-3	102	90	58	2,224	26	118	176	358	58	134	54	38	16	19	294	86	3,851	5,152
3-4	45	54	61	112	243	218	214	262	192	118	58	669	192	61	102	141	2,742	7,894
4-5	272	64	41	16	224	368	717	352	371	80	19	224	301	64	93	250	3,456	11,350
5-10	3,395	18,959	32,001	25,760	40,770	54,533	36,467	28,932	19,214	4,217	2,957	4,961	1,765	1,361	1,433	1,134	227,859	289,209
10-20	6,743	12,805	36,705	29,830	70,762	150,630	247,846	207,202	53,673	10,614	13,066	3,930	3,292	5,211	1,802	21,042	875,153	1,164,362
20-30	4,762	11,021	83,556	21,447	39,043	73,073	84,458	35,734	20,566	10,106	8,106	6,864	7,049	3,742	3,057	4,777	417,361	1,581,723
30-40	9,637	43,147	182,602	15,685	31,111	21,055	23,005	8,934	9,346	5,682	4,099	7,270	7,908	5,446	25,094	38,961	438,982	2,020,705
40-50	15,198	93,911	291,625	17,946	15,086	13,237	11,027	7,278	9,204	6,199	4,369	5,065	16,672	12,417	9,794	27,755	566,783	2,577,488
SECTOR TOTALS	40,180	180,064	626,978	113,157	197,284	313,241	404,409	289,065	112,672	37,208	32,782	29,030	37,205	28,334	41,188	94,188	2,577,448	2,377,488

Source: Ref. 6

026

4251

TABLE 3-3

Approximate FMPC On-Site Population

Building	1st Shift	2nd Shift	3rd Shift
Weekdays			
Administration	93	1	
Health and Safety	48	1	1
Guardhouse (security)	11	4	4
Service Building	9	2[a]	1
Laboratory	67	1	1
Engine House and Garage	10	3	2
Mechanical Shops	25	4[b]	0
Storeroom	15	0	0
Boiler Plant	10	4	2
Water Treatment	7	3	2
Heavy Equipment Garage	6	0	0
Pilot Plant	1	0	0
Plant 1	17	0	0
Plant 2 and 3	7	4	4
Plant 4	19[c]	10	6
Plant 5	36[d]	14	8
Plant 6	28	2	0
Plant 8	4	2	2
Plant 9	12	5	3
Unassigned	88	3	3
Total	513	63	39
Weekends			
Health and Safety	1	1	1
Security	5[e]	5[e]	5[e]
Power Plant	3	3	2
Water Treatment	4	0	0
Total	13	9	8

[a] Includes 1 porter who could be anywhere on the site.
[b] Could be anywhere on the site.
[c] Includes 2 employees assigned to Plant 4 Mechanical shop who could be anywhere on the site.
[d] Includes 8 employees assigned to Plant 5 Mechanical shop would be anywhere on the site.
[e] Includes employees at the guardhouse and on patrol.

Source: Reference 3.

samplers at the FMPC boundaries (Table 4-3) are analyzed for gross alpha and gross beta and for uranium. Annual composites from each are analyzed for thorium. The average airborne concentrations for the period 1974-1980 are summarized in Table 3-4. Average concentrations at the boundary sampling stations were no greater than 0.1 percent of the DOE limit for effluent to offsite areas. Maximum concentrations were on the order of 10 percent or less of the applicable DOE limits.

Since the K-65 tanks contain large quantities of radium-226 and are cracked, measurement of ambient air radon-222 concentration was added to the air monitoring program in 1980. Results of the track-etch measurement technique sampling made at the air particulate monitoring stations, the K-65 tanks, and off-site locations are presented in Table 3-5. Although it is known that radon is emanating from the K-65 tanks, concentrations at the air particulates monitoring stations are not significantly different from the off-site monitoring locations and none exceed the DOE limit of 3 pCi/l for uncontrolled areas.

In July 1980, grab samples of breathing zone air (4-5 feet above surface) were collected in scintillation flasks at various points within the fence surrounding the K-65 tanks. These results are presented in Table 3-6 and indicate that the DOE limit of 100 pCi/l for airborne radon-222 in controlled areas is exceeded on occasion very near the tanks. Access of personnel to the area is limited and controlled by a security fence.

It is interesting to note that the highest concentrations of airborne radioactivity occur at monitoring stations other than those in the most probable wind direction. The source of most of these particulates is probably the production area rather than the Waste Storage Area. Although the radon data shows no clear trend, the results are more consistent with the wind frequency distribution.

TABLE 3-4

Concentrations of Radioactive Contaminants in Air During 1974-1980[a] (uCi/ml)

Contaminant	Sampling Point[b]	Number of Samples	Maximum Concentration	Average Concentration	DOE Effluent Limit[c]
Uranium[d]	BS 1	305	8.2×10^{-14}	7.5×10^{-15}	5×10^{-12} (1×10^{-10})
	BS 2	308	4.2×10^{-14}	6.2×10^{-15}	
	BS 3	309	2.3×10^{-13}	9.6×10^{-15}	
	BS 4	307	7.5×10^{-14}	2.1×10^{-15}	
	BS 5	306	1.2×10^{-13}	3.8×10^{-15}	
	BS 6	304	8.1×10^{-14}	4.9×10^{-15}	
Thorium[e]	BS 1	6	2.9×10^{-17}	3.5×10^{-17}	1×10^{-12} (3×10^{-11})
	BS 2	6	3.7×10^{-17}	3.4×10^{-17}	
	BS 3	6	4.4×10^{-17}	2.3×10^{-17}	
	BS 4	6	3.3×10^{-17}	1.8×10^{-17}	
	BS 5	6	3.3×10^{-17}	2.1×10^{-17}	
	BS 6	6	3.6×10^{-17}	2.1×10^{-17}	
Gross Alpha	BS 1	305	7.6×10^{-14}	7.8×10^{-15}	2×10^{-14} (6×10^{-13})
	BS 2	308	5.5×10^{-14}	6.3×10^{-15}	
	BS 3	309	2.2×10^{-13}	7.2×10^{-15}	
	BS 4	307	6.6×10^{-14}	3.2×10^{-15}	
	BS 5	306	1.8×10^{-13}	4.6×10^{-15}	
	BS 6	304	7.8×10^{-14}	5.3×10^{-15}	
Gross Beta	BS 1	305	5.7×10^{-13}	3.3×10^{-14}	2×10^{-14} (6×10^{-13})
	BS 2	308	4.3×10^{-13}	3.5×10^{-14}	
	BS 3	309	6.0×10^{-13}	4.2×10^{-14}	
	BS 4	307	4.8×10^{-13}	3.6×10^{-14}	
	BS 5	306	4.0×10^{-13}	4.0×10^{-14}	
	BS 6	304	3.7×10^{-13}	4.2×10^{-14}	

[a] Except 1977.
[b] See sampling locations in Figure 4-3.
[c] For insoluble isotope in uncontrolled areas, limit for controlled areas enclosed in parentheses.
[d] DOE limit given for U-238.
[e] DOE limit given for Th-232.

Source: References 3, 7, 8, and 9.

TABLE 3-5

Concentrations of Radon In Air
1980-1981
(pCi/l)

Sampling Point[a]	Sampling Period 7/3/80-10/3/80	10/3/80-3/13/81	3/13/81-5/26/82	5/26/81-9/28/81	9/28/81-2/2/82	Average
BS 1	0.44	0.11	0.40	0.94	0.85	0.55
BS 2	0.54	0.17	0.44	1.35	0.48	0.60
BS 3	0.49	0.22[b]	0.13	0.53	0.60	0.39
BS 4	0.19	0.05	0.40	0.66	0.48	0.31
BS 5	0.65[c]	0.08	0.59	1.48[c]	0.36	0.59
BS 6	-	0.34	0.30	0.80	0.55	0.57
BS 7	-	-	0.30	1.07	0.73	0.70
K-65 tank[h]	180.22[g]	80.08	135.75[c]	-	120.73	129.20
Bkg RCH[e]	-	-	0.60[d]	0.80	0.60	0.67
Bkg MLC[f]	-	-	-	0.94	0.36	0.65

[a] See Figure 4-3 for sampling locations
[b] Lower part of cup cracked
[c] Split in filter reported
[d] Sampling began 4/7/81
[e] Background sampling location approximately 10 miles east of the FMPC site.
[f] Background sampling location approximately 6.7 miles southwest of the FMPC site.
[g] Sampling began 6/13/80
[h] Sample taken on the south rail of the north K-65 tank (since not all K-65 data was labeled with sampling location, it was assumed that the same sampling location was used for each sampling period).

Source: Reference 3.

TABLE 3-6

Ambient Air Radon Concentrations Within
the K-65 Tank Area Security Fence
(pCi/l)

Date	Location	Concentration	Comments
7/15/80	Atop north tank west edge	2590.0	No air movement
7/16/80	Just east of north tank embankment	17.7	Very slight westerly breeze
7/17/80	Just east of overpile, between tanks	101.6	Approximately 85°F, NW wind at approximately 2 mph
7/24/80	NE of north tank, near near gate (upwind)	0.6	Very light easterly wind, hot
7/24/80	W of north tank, near fence (downwind)	38.0	
7/22/80	Counting room air Counting room air employee's breath	0.4 0.1 0.3	These were taken as a system check

Source: Reference 10.

3.2.2 Soils and Sediments

Soil samples are collected annually near the six boundary air sampling stations to check for deposition of uranium from stack effluents. The concentrations in the soil samples at most locations are slightly above the normal concentrations of uranium in the local area, (1-4 ug/g) (Ref. 2). Table 3-7 presents a summary of the results of the soil sample analyses for the years 1978-1980. In these years, sample results ranged from a low of 9 ug uranium per gram of soil at location BS-4 to a high of 110 ug uranium per gram of soil at location BS-3. Location BS-3 also has the highest reported airborne uranium concentrations.

Sediment samples were collected from the banks of the Miami River and analyzed for uranium to determine if material was accumulating below the site outfall. The results of sediment sampling do not indicate any buildup of uranium along the edge of the water where settling might be expected to occur. Most of the uranium present in the site effluent is soluble, probably existing as a carbonate complex (Ref. 2). Periodic flooding, which is severe enough to cause channel alteration and bank erosion, scours the river bed and banks and prevents any long-term sediment accumulation.

3.2.3 Ground Water

The chemical quality of natural ground water in the Great Miami River valley aquifer is dominated by calcium bicarbonate with total dissolved solids in the range of 300 to 600 milligrams per liter (mg/L) (Ref. 4). In some areas natural concentrations of iron and manganese exceed the USEPA Secondary Drinking Water Standards. The range and average concentrations of various constituents found in samples from the regional aquifer are shown in Table 3-8.

TABLE 3-7

Uranium in Soil, 1978 - 1980

Sampling Point[a]	Average (ug/g)	Average (uCi/g)[c]	Range[b] (ug/g)	Range[b] (uCi/g)[c]
BS 1	16.3	5.5×10^{-6}	12-23	$4.0 \times 10^{-6} - 7.8 \times 10^{-6}$
BS 2	19.7	6.6×10^{-6}	17-21	$5.7 \times 10^{-6} - 7.1 \times 10^{-6}$
BS 3	91.3	3.1×10^{-5}	62-110	$2.1 \times 10^{-5} - 3.7 \times 10^{-5}$
BS 4	10.3	3.5×10^{-6}	9-11	$3.0 \times 10^{-6} - 3.7 \times 10^{-6}$
BS 5	14.0	4.7×10^{-6}	11-16	$3.7 \times 10^{-6} - 5.4 \times 10^{-6}$
BS 6	14.7	4.9×10^{-6}	11-19	$3.7 \times 10^{-6} - 6.4 \times 10^{-6}$

[a]See Figure 4-3 for sampling locations.
[b]Error estimates not available.
[c]Based on the assumption that all the uranium is U-238.

Source: References 2, 7, 8, and 9.

TABLE 3-8

Typical Ground Water Quality in the
Great Miami River Valley Aquifer
(mg/L)

Constituent	Range of Concentrations	Average Concentrations	Interim Primary Drinking Water Standards	Secondary Drinking Water Standards (Recommended)
Calcium	73-210	97.0	—	—
Magnesium	20-82	31.0	—	—
Sodium	2.5-31	12.3	—	—
Potassium	0.9-3.6	1.9	—	—
Iron	0.00-8.2	0.097	—	0.3
Manganese	0.01-0.45	0.17[a]	—	0.05
Bicarbonate	268-500	344.0	—	—
Sulfate	24-424	80.0	—	250.0
Chloride	5.5-48	19.0	—	250.0
Fluoride	0.0-0.5	0.013	—	1.4-2.4
Nitrate (as NO_3)	0-18	3.0	44.3	—
Phosphate	0.11-7.5	—	—	—
Phenols (as C_6H_5OH)	0.001-0.011[b]	—	—	—
Specific conductance (micromhos)	550-1,510	708.0	—	—
pH (standard units)	7.0-7.7			6.5-8.5

[a]Average calculated on results from 23 samples; 7 other samples contained concentrations of manganese below detection limit of analytical method.
[b]Range calculated on results from 8 samples; 5 other samples contained concentrations of phenols below detection limit of analytical method.

Source: Reference 4.

0036824

At the Feeds Materials Production Center, the three production water wells and nine test wells are sampled regularly and the water analyzed for selected chemical species and radiological constituents. Results of quarterly sampling of the test wells during 1981 are summarized in Tables 3-9 and 3-10. These results and others for period 1976-80 show considerable variation of some constituents between different wells and with time.

As indicated by Table 3-9, recent concentrations of nitrate in Test Well 1 (shallow) are significantly higher than in other wells. Nitrate is the stable form of nitrogen in shallow ground water, which usually contains dissolved oxygen. Under these conditions it is characteristically very mobile, undergoing little transformation or absorption onto sediments. The concentrations of nitrate in this area of the upper aquifer have been declining steadily since 1977 with annual mean values of 301 mg/L (as nitrate) in 1977, 188.5 mg/L in 1978, 155 mg/L in 1979, and 90.8 mg/L in 1980 before reaching 63 mg/L in 1981. As shown in Figures 3-3 and 3-4, this decline in levels of ground water contamination closely follows decreases in the concentrations of nitrate at Manhole 175. During 1976 the concentrations of nitrate in the pits exceeded 5,500 mg/L as nitrate; however, this fell abruptly during 1976 and 1977 and at present is approximately 400 mg/L.

This apparent correlation between concentrations of nitrate in the pits and the nearby upper aquifer zone suggests that some seepage of wastewater from the pits into the shallow ground water has occurred. Operating procedures changed in 1970 and wastewater now flows into Pit 5 which has a plastic membrane liner. Between 1970 and 1981, Pit 3, which had previously received the waste, was progressively covered over with fill. It is unclear whether these activities have reduced seepage from the waste storage area.

0036825

TABLE 3-9

Concentrations of Non-Radioactive Contaminants in Ground Water, 1981
(mg/L)

Well[a]	Date of Sampling	pH	Chloride	Nitrate	Sulfate
Test Well 1 Shallow	01/09/81	7.5	34	100	90
	04/24/81	7.6	33	80	85
	08/07/81[b]	-	-	-	-
	11/20/81	7.5	24	9.2	79
Test Well 1 Deep	01/09/81	7.4	22	3.4	37
	04/24/81	7.6	31	2.0	80
	08/07/81	7.5	26	2.1	54
	11/20/81	7.5	25	1.6	52
Test Well 3 Shallow	01/09/81	7.6	20	2.5	70
	04/24/81	7.5	19	1.4	74
	08/07/81	7.4	20	1.3	94
	11/20/81	7.5	21	1.8	88
Test Well 4 Deep	01/09/81	7.5	25	2.6	54
	04/24/81	7.5	22	12	76
	08/07/81	7.5	19	11	75
	11/20/81	7.5	23	3.7	69
Test Well 5 Shallow	01/09/81	7.5	18	2.2	98
	04/24/81	7.5	21	1.4	82
	08/07/81	7.5	21	5.4	77
	11/20/81	7.4	16	35.1	81
Test Well 8 Shallow	01/09/81	7.8	18	1.9	38
	04/24/81	7.6	23	1.5	49
	08/07/81	7.5	24	2.1	76
	11/20/81	7.7	23	1.4	53
Test Well 8 Deep	01/09/81	7.5	12	1.4	7
	04/24/81	7.5	12	1.3	7
	08/07/81	7.4	13	1.3	8
	11/20/81[b]	-	-	-	-
Test Well 9 Shallow	01/09/81[b]	-	-	-	-
	04/24/81	7.8	19	8.0	63
	08/07/81	7.6	20	2.2	75
	11/20/81	8.8	20	1.5	67
Old Administration Building	01/09/81	6.5	576	9.8	795
	04/24/81	6.8	593	7.3	793
	08/07/81	6.5	687	9.6	808
	11/20/81	7.2	687	6.1	673
Interim Primary Drinking Standard				44.3	
Secondary Drinking Water Standard (Recommended)			250		250

[a] See Figure 4-4 for sampling locations.
[b] No sample
Exceeds drinking water standards.
Source: Reference 3.

TABLE 3-10

Concentrations of Radioactive Contaminants
in Ground Water, 1981
(pCi/ml)

Contaminant	Sampling Point[a]	Number of Samples	Maximum Concentration	Average Concentration	Interim Primary Drinking Water Standard
Uranium[c]	T-1S[b]	3	3.7×10^{-6}	2.3×10^{-6}	
	T-1D	4	1.0×10^{-6}	1.0×10^{-6}	
	T-3	4	1.7×10^{-6}	1.3×10^{-6}	
	T-4	4	3.0×10^{-6}	2.7×10^{-6}	
	T-5	4	2.7×10^{-6}	2.0×10^{-6}	
	T-8S	4	4.7×10^{-6}	2.0×10^{-6}	
	T-8D	3	1.3×10^{-6}	1.7×10^{-6}	
	T-9	3	2.0×10^{-6}	1.7×10^{-6}	
Gross Alpha	T-1S	3	5.4×10^{-6}	5.4×10^{-6}	1.5×10^{-2}
	T-1D	4	4.1×10^{-6}	2.7×10^{-6}	
	T-3	4	7.2×10^{-6}	5.4×10^{-6}	
	T-4	4	6.7×10^{-6}	5.4×10^{-6}	
	T-5	4	8.1×10^{-6}	5.4×10^{-6}	
	T-8S	4	8.1×10^{-6}	4.1×10^{-6}	
	T-8D	3	4.1×10^{-6}	3.2×10^{-6}	
	T-9	3	7.2×10^{-6}	5.9×10^{-6}	
	OAB[d]	4	3.8×10^{-5}	1.6×10^{-5}	
Gross Beta	T-18	3	3.4×10^{-5}	2.6×10^{-5}	5.0×10^{-2}
	T-1D	4	1.6×10^{-5}	1.2×10^{-5}	
	T-3	4	2.5×10^{-5}	1.7×10^{-5}	
	T-4	4	4.1×10^{-5}	1.8×10^{-5}	
	T-5	4	1.8×10^{-5}	1.4×10^{-5}	
	T-8S	4	2.3×10^{-5}	1.1×10^{-5}	
	T-8D	3	2.2×10^{-5}	1.2×10^{-5}	
	T-9	3	1.8×10^{-5}	1.5×10^{-5}	
	OAB	4	6.4×10^{-5}	4.4×10^{-5}	

[a] See Figure 4-4 for sampling locations.
[b] T = test well, S = shallow, D = deep.
[c] Assumed that all uranium was U_{238}.
[d] OAB = Old Administration Building.

Source: Reference 3.

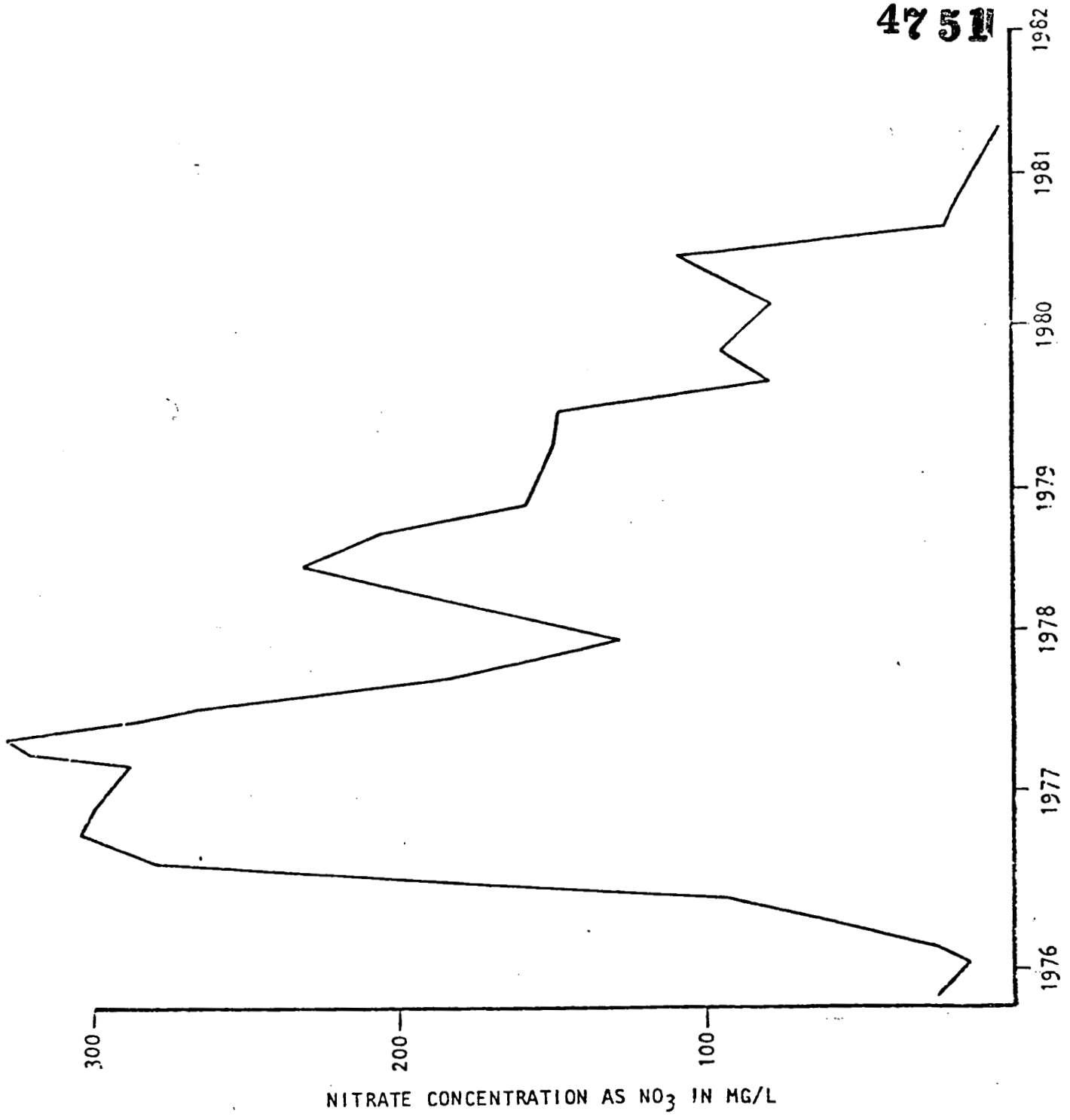


FIGURE 3-3
CONCENTRATION OF NITRATE
IN TEST WELL #1 - SHALLOW
1976-1981

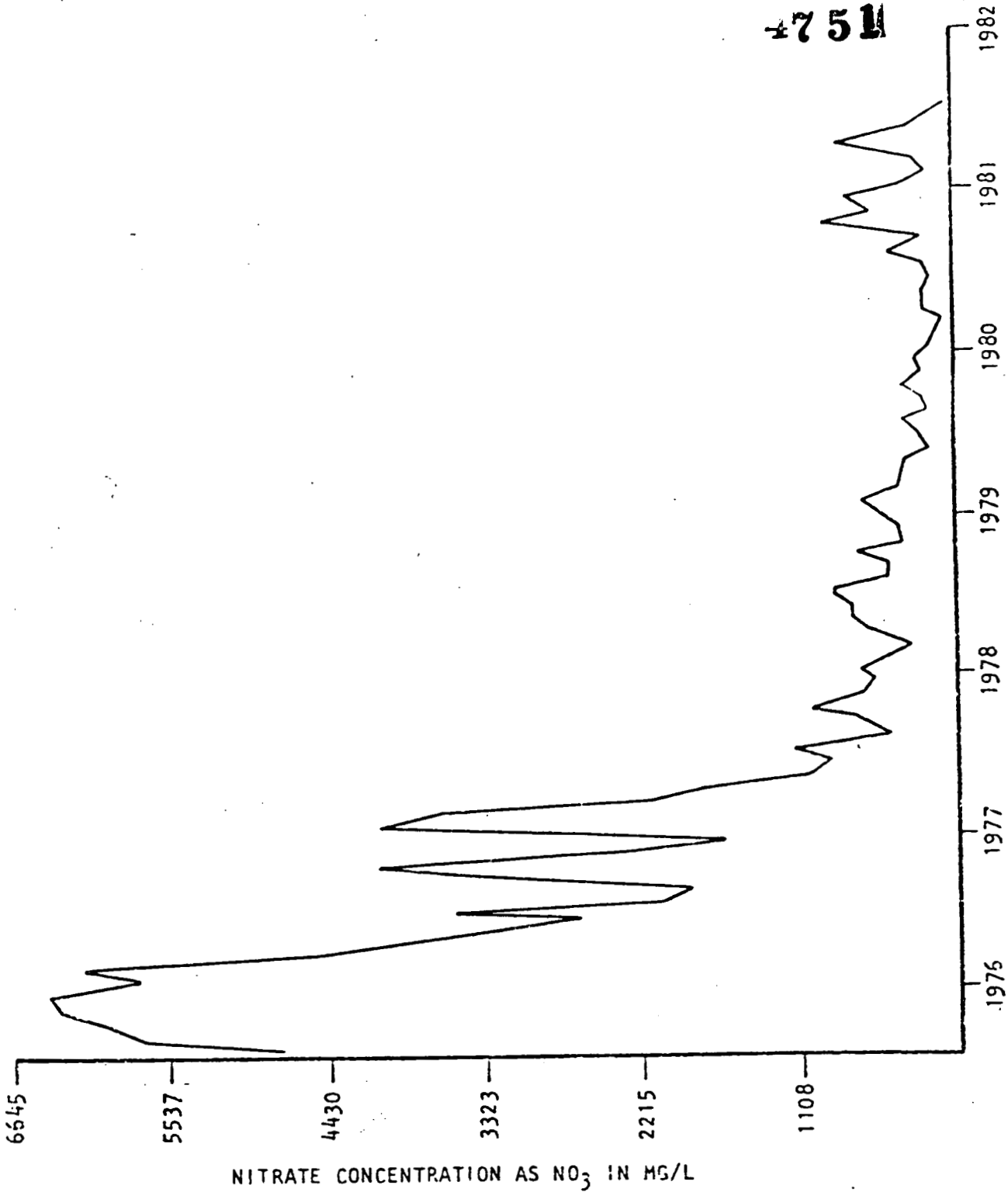


FIGURE 3-4
CONCENTRATION OF NITRATE IN OUTFALL
1976-1981

0036829

Nitrate concentrations in the other wells are in general close to background levels, and it is not possible to determine the areal extent or direction of movement of any plume of contaminated water which may be present. The levels of nitrate in Test Well No. 1 (deep) have historically been low which suggests that the clay lens has effectively prevented flow of the contaminated water into the lower aquifer in the immediate area of the waste storage pits. It is possible, however, that there is a flow direction and hydraulic gradient in the upper aquifer quite different from the probable easterly flow direction in the lower aquifer which is pumped for water supply. The direction of movement and present location of the contamination plume therefore cannot be predicted.

The concentration of uranium in quarterly samples from all wells were reported for 1980 and 1981; additional results were reported for Test Well No. 1 (shallow) from 1976 to 1979. The concentration of uranium in natural ground water is reported to range from 0.001 mg/l to 0.010 mg/L (Ref. 11). The concentrations of uranium in samples of water from both the upper and lower alluvial aquifers at the site are usually below 0.005 mg/L. In Test Wells No. 1 (shallow), No. 4, No. 5, and No.9, several samples exceeded 0.005 mg/L of uranium although there was considerable variation in concentration. The concentrations found do not exceed 0.020 mg/L.

The ground water concentrations of other reported chemical and radiological species in the waste storage area, in general, do not exceed recommended and mandatory drinking water standards. There are however elevated levels of chloride and sulfate and occasional excessive levels of gross alpha and gross beta in the Old Administration Building Well. The source of these excursions is unknown.

3.2.4 Surface Water

Analyses of samples collected from the Great Miami River showed that radium was present at the greatest percentage of the specified

TABLE 3-11

4751

Concentrations of Radioactive Contaminants in Surface Water 1971-1980[a] (uCi/ml)

Contaminant	Sampling Point[b]	Number of Samples	Maximum Concentration	Average Concentration	DOE Standard[d]
Uranium	W1	522	6.7×10^{-8}	2.2×10^{-9}	6×10^{-7} (2×10^{-5})
	W2	1826	1.8×10^{-7}	4.8×10^{-10}	
	W3	526	6.0×10^{-9}	1.6×10^{-9}	
	W4	265	8.0×10^{-9}	1.9×10^{-9}	
	W5	104	7.8×10^{-9}	1.4×10^{-9}	
	W7	61	6.4×10^{-8}	7.5×10^{-9}	
	W8	45	2.4×10^{-8}	4.8×10^{-9}	
Thorium	W2	54	9.0×10^{-12}	5.6×10^{-13}	2×10^{-6} (5×10^{-5})
Radium-226	W1	155	2.0×10^{-9}	6.3×10^{-10}	3×10^{-8} (4×10^{-7})
	W2	138	7.4×10^{-9}	1.3×10^{-11}	
	W3	155	3.6×10^{-9}	4.9×10^{-10}	
	W4	102	9.0×10^{-10}	4.5×10^{-10}	
	W5[c]	8	4.5×10^{-10}	4.5×10^{-10}	
	W7[c]	11	4.5×10^{-10}	4.5×10^{-10}	
Radium-228	W1	148	2.2×10^{-9}	5.1×10^{-10}	3×10^{-8} (8×10^{-7})
	W2	147	5.8×10^{-11}	3.2×10^{-12}	
	W3	148	1.8×10^{-9}	5.8×10^{-10}	
	W4	102	9.0×10^{-10}	5.1×10^{-10}	
	W5[c]	8	4.5×10^{-10}	4.5×10^{-10}	
	W7[c]	11	4.5×10^{-10}	4.5×10^{-10}	
Gross Alpha	W1	363	1.4×10^{-7}	6.4×10^{-9}	3×10^{-8} (4×10^{-7})
	W2	1095	5.8×10^{-10}	7.2×10^{-10}	
	W3	365	1.4×10^{-7}	7.9×10^{-9}	
	W4	265	1.3×10^{-7}	1.2×10^{-6}	
	W5	104	5.6×10^{-8}	5.4×10^{-7}	
	W7	61	7.2×10^{-8}	7.3×10^{-7}	
	W8	45	4.5×10^{-8}	5.3×10^{-7}	
Gross Beta	W1	523	4.5×10^{-7}	1.9×10^{-8}	3×10^{-8} (4×10^{-7})
	W2	1826	9.2×10^{-7}	8.1×10^{-9}	
	W3	525	9.1×10^{-8}	1.6×10^{-8}	
	W4	265	3.9×10^{-7}	1.7×10^{-8}	
	W5	104	9.0×10^{-8}	1.6×10^{-8}	
	W7	61	4.5×10^{-8}	1.4×10^{-8}	
	W8	45	7.7×10^{-8}	2.3×10^{-8}	

[a] Not all parameters were reported each year.
[b] See Figure 4-3 for sampling locations.
[c] 1980 data only.
[d] Designates standards for soluble isotopes in uncontrolled areas. Controlled area limits are enclosed in parenthesis.

Source: References 7, 8, and 9.

0036831

041

limits. Table 3-11 shows radioactive contaminant concentrations found in the Great Miami River (sampling points W1 and W3) in 1980. No significant difference was observed between upstream and downstream concentrations of radium and uranium.

Uranium, gross alpha and gross beta data for Paddy's Run are also presented in Table 3-11 (sampling point W8). At the downstream sampling point, the average uranium concentration was less than 0.05% of the DOE guide for uncontrolled areas. Average concentrations of gross alpha and beta radioactivity were within the DOE limits for unidentified emitters.

The major non-radioactive water quality problem stems from low dissolved oxygen and ammonia toxicity as a result of municipal and industrial discharges (Ref. 2) Data on non-radioactive contaminants obtained by the U.S. Geological Survey, at their water quality monitoring station on the Great Miami River at New Baltimore (approximately 3.5 river miles downstream from FMPC), is presented in Table 3-12.

TABLE 3-12

Concentrations of Non-Radioactive Contaminants in Surface Water 1980 (mg/L)

Contaminant	Sampling Point[a]	Number of Samples	Maximum Concentration	Average Concentration	DOE Standard
Fluoride	W1	53	1.2	0.6	2
	W3	53	1.2	0.5	
	W4	53	1.5	0.6	
	W5	14	0.7	0.3	
	W7	12	0.7	0.3	
	W8	16	0.4	0.2	
Nitrate Nitrogen	W1	53	11.0	5.2	22
	W3	53	11.0	5.1	
	W4	53	11.0	5.0	
	W5	14	3.5	2.3	
	W7	12	3.4	2.3	
	W8	14	3.4	2.3	
Chloride	W1	53	95.0	47.0	250
	W3	53	94.0	47.0	
	W4	53	96.0	47.0	
	W5	14	34.0	22.0	
	W7	12	34.0	18.0	
	W8	16	165.0	40.0	
pH[b]	W1	53	8.7	7.7[c]	6.5-9.0
	W3	53	8.8	7.6	
	W4	53	8.9	7.7	
	W5	51	8.6	7.1	
	W7	32	8.4	7.6	
	W8	20	7.9	7.2	

[a] See Figure 4-3 for sampling locations.
[b] pH is reported in standard units.
[c] Minimum (average not applicable).

Source: Reference 9.

4.0 FACILITY AND PROCESS DESCRIPTION

4.1 Facilities

The FMPC uses three types of facilities for the long term storage of wastes: K-65 tanks; metal oxide tanks; waste storages pits. There are two K-65 tanks, two metal oxide tanks and six waste storage pits. The locations of these facilities in relation to the plant are shown in Figure 4-1. A summary of relevant characteristics of each facility (i.e., waste content, lining or walls, status) is given in Table 4-1.

The six waste pits are identified by number based on the chronological sequence of their construction. They are further identified as "dry" or "wet" pits. This distinction is made on the basis of the physical state of the material as it is placed in the pit. If the material is placed as a slurry, the pit is known as a wet pit. If the material is placed as a dry solid, the pit is known as a dry pit (Ref. 12).

4.1.1 Dry Waste Pits

Pits 1, 2, 4, and 6 are dry waste pits. Pits 1 and 2 are essentially "inground" facilities which are used for storage of wastes such as filter cakes, graphite, brick, scrap and sump liquor. Maximum depths of Pits 1 and 2 were 17 and 13 feet, respectively. Pit 1 has a total capacity of 1,080,000 cubic feet and Pit 2 has a capacity of 351,000 cubic feet. The walls of both pits were lined with 1.5 to 2.0 feet of compacted clay. Both pits have been filled, covered with clean, uncontaminated fill and graded to provide surface drainage away from the pits. (Ref. 2).

Pit 4 is a partially filled pit used principally for the storage of large dry waste solids such as depleted graphite and non-burnable

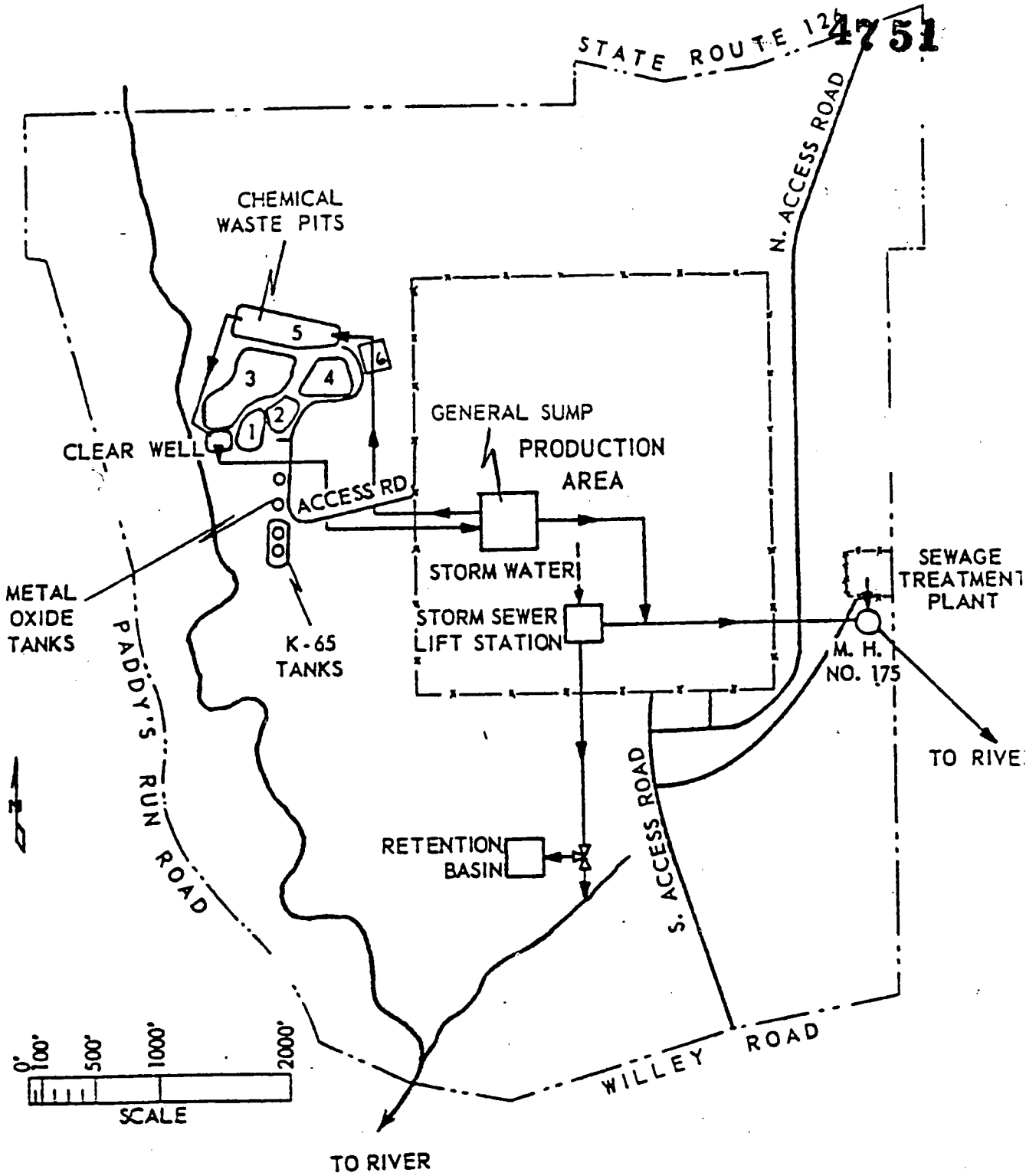


FIGURE 4-1
WASTE TREATMENT AND STORAGE LOCATIONS

TABLE 4-1

Waste Storage Facility Characteristics

Facility	Bottom Elevation Feet (msl)	Contents	Lining/Walls	Status
Pit 1	560[a]	filter cakes, graphite, brick scrap and sump liquor	1.5-2.0 ft compacted clay	Closed and covered
Pit 2	570[a]	filter cakes, graphite, brick scrap and sump liquor	1.5-2.0 ft compacted clay	Closed and covered
Pit 3	548	waste slurries from process plants	1.0 ft compacted clay	Closed and covered
Pit 4	560	process residues, trailor cakes, slurries, raffinates, depleted graphite, non-burnable trash	1.0 ft clay	Active
Pit 5	558	waste slurries from process plants	1/16 inch rubberized elastromeric membrane	Active
Pit 6	560	fine dry waste materials	elastromeric membrane	Active
Clear Well[a]	?	effluent	clay	Active
K-65 tank		radium containing residues from pitchblende ore processing	8 inch concrete post stressed with high tensile steel wire, earth embankment	Inactive
Metal oxide tank		residues from processing of non-pitchblende ore concentrates	8 inch concrete post stressed with high tensile steel wire	Active

[a]Estimated.

trash. It also receives process residues, trailer cakes, slurries, raffinates, chloride contaminated water, etc. Lime slurry from the general Sump is pumped to Pit 4, by way of a fire hose approximately 250 feet in length, in order to precipitate any uranium in solution (Ref. 13).

This pit is also lined with 2.0 feet of clay. It has a maximum depth of 24 feet and a total capacity of 1,431,000 cubic feet. As of August 1979, the pit had been filled with 1,402,380 cubic feet of waste (Ref. 3).

Pit 6 is the most recently built pit. It is approximately 25 feet deep with dimensions of 180 by 180 feet at the top and 60 by 60 feet at the bottom. The total capacity of this pit is 390,000 cubic feet. The dike of the pit is 6 feet across the top and has an internal slope of 0.40, and an external slope of 0.33. The pit is lined with an impermeable elastomeric membrane and is used for the storage of fine dry waste materials.

4.1.2 Wet Waste Pits

Pits 3 and 5 are wet waste storage pits. These pits have functioned as settling basins for the liquid process waste streams which are generally routed from the process plants through the General Sump to the open pit. Three process waste streams are routed directly to Pit 5.

Pit 3 was constructed at the west end of the storage area plateau. Soil removed during the excavation was used to form the pit west wall. The soil was placed in 6 to 8 inch layers and compacted with sheepsfoot rollers. A natural layer of clay formed the pit bottom. After the excavation, the pit walls were covered with a thick clay layer. Maximum depth of this pit was 24 feet from the pit bottom to the top of the embankment. The reported elevations of

the bottom of the pits suggest that 5-10 feet of relatively impermeable clay till separate the bottom of Pit 3 and the permeable sand and gravel of the aquifer. The total capacity of Pit 3 is 6,115,500 cubic feet and the surface area is 6.80 acres. A typical section of the dike around Pit 3 is 10 feet across the top with an internal slope of 0.66 and an external slope of 0.7.

In 1976, Pit 3 was closed with respect to its function as a settling basin. The remaining capacity was filled with magnesium fluoride slag from Plant 5, dirt and cinders. The pit is now covered with a layer of clean fill of unknown thickness (Ref. 2).

Pit 5 is a settling basin with a rubberized elastomeric membrane lining. The lining is highly resistant to acids, alkalis and oxygenated solvents; however, it has been observed to have several significantly large tears below the water level. These tears are scheduled to be repaired in the summer of 1982. The condition and efficiency of the rest of the Pit 5 liner is unknown. It is believed that Test Well No. 7 is located beneath this liner, having been cut off and plugged with concrete during pit construction.

Pit 5 has a capacity of 3,105,000 cubic feet and a surface area of about 3.6 acres. It is 25 feet deep and the top of the pit embankment is about 10 feet above the surrounding ground surface. The Pit 5 dike on the side closest to Pit 3 is described to be 6.5 feet across the top with an external slope of 1.21 and an internal slope of 0.64.

Neutralized waste slurry enters the east end of Pit 5 and the clear supernate is discharged through an overflow tower at the west end. From the tower, the liquid flows by gravity to the Clearwell where it is sampled and pumped for offsite discharge. The Clearwell is a clay lined pit 27 feet deep with a freeboard of at least 3 feet (Ref. 3).

4.1.3 Storage Tanks

There are two K-65 tanks and two metal oxide tanks used for long term storage of waste at the FMPC. These tanks are cylindrical concrete structures, 80 feet in diameter and approximately 27 feet high. Each tank has a capacity of 125,000 cubic feet. The floor of the tanks are concrete approximately 3 inches thick. The walls of the tanks are concrete, 8 inches thick. The walls are poststressed with high tensile steel wire and the wires are protected by a 0.75 inch grout coating. Access to the K-65 tanks is restricted by a fence which surrounds both tanks.

The two K-65 tanks store radium bearing residues from pitchblende ore processing. The estimated volume of material stored in these tanks is 195,000 cubic feet. Assuming that this volume is distributed evenly between the two tanks, each tank is approximately three quarters full. Only the south metal oxide tank contains waste materials. This tank stores residues from processing of non-pitchblende ore concentrates which contain residual radium. The north tank is empty.

In 1964, the two K-65 tanks were enclosed with an earth embankment to protect them from weathering. Some damage had occurred to the gunite coating of the tanks, but this was repaired before the embankment was constructed. Hairline surficial cracks have also been observed in the domes of the K-65 tanks which remain uncovered and in the metal oxide tanks. As mentioned in Section 3.2.1, radon measurements taken above tlv K-65 tanks have revealed leakage of radon.

4.1.4 Piping and Valves

Liquid wastes are transported between the General Sump and the waste storage area via two 6 inch diameter pipes. These pipes exit the plant on the west side where they become enclosed in a concrete trench that is covered with slabs of concrete. The trench extends to

the fence of the K-65 tanks at which point the pipes bend north and become buried underground. The two pipes then branch and one winds north between Pits 2, 3 and 4 to Pit 5 while the other turns west to the Clearwell. At one point near the gravel road between the metal oxide tank area and Pit 2, the ground dips and a short section of the pipe going to Pit 5 is exposed.

On the southern dike of Pit 5 the pipe from the General Sump connects to a T of three berm valves. The pipe attaches at the valve on the west side of the T, a fire hose leading to Pit 4 is connected at the middle valve which lies in an extension above the plane of the other two valves and the eastern valve is connected to a pipe leading to the eastern end of Pit 5. With these valves, the wastes can be directed from the General Sump to Pit 4 or 5, from either of the two pits to the other and from either pit back to the General Sump, although normally wastes are only pumped from the General Sump to Pit 5.

An additional pipe originates in the tower at the west end of Pit 5 and extends, buried in the dike of Pit 3, to the Clearwell. This pipe transports Pit 5 supernate to the Clearwell. The transfer is controlled by a scissors valve in the tower. During, and immediately following periods of heavy rainfall, this valve is closed to retain solids which become suspended due to agitation. The other 6 inch pipe, which connects the Clearwell and the General Sump, is used to transport Clearwell supernate back to the General Sump.

4.1.5 Waste Inventory

Wastes stored in the FMPC waste storage area contain radioactive wastes, small quantities of pyrophoric wastes and neutralized toxic chemicals. The radionuclides encountered in the wastes are basically uranium, thorium and the radioactive daughters of each. No high level radioactive wastes are stored in this area. The pyrophoric waste materials encountered include magnesium fluoride with free magnesium particles, uranium turnings, uranium briquettes, and depleted

graphite. Toxic chemicals used in the plant processes and subsequently sent to the storage pits include: anhydrous ammonia, hydroflouric acids, hydrochloric acid and various nitrates, e.g., aluminum nitrate. These chemicals are neutralized to a pH of 9.0, before they are sent to the storage pits.

Solid Wastes

There are four principal types of solid wastes generated at the present time at FMPC. These are discharged without treatment to chemical storage Pits 4 and 6. They are:

a) Depleted Uranium Residues - Process residues of depleted uranium (0.142-0.40% ^{235}U) that are not suitable for remelt or containing uranium values in low amounts not economical for recovery.

b) Low Grade Thorium Residues - Process residues that similarly cannot be economically processed for recovery of thorium values.

c) Contaminated Ceramics - Slightly contaminated refractories from production electric furnaces discarded during repairs.

d) General Refuse - Various types of trash, generally noncombustible, which have become slightly contaminated through incidental contact with radioactive substances.

Before storage these wastes are reviewed to determine that they (1) are insoluble, (2) do not present a fire hazard, and (3) do not include organic liquids which could possibly present a water pollution problem.

Liquid Wastes

Liquid wastes are generated to some degree in every operation at FMPC. All of the major process areas have individual treatment facilities where virtually all of the radioactive materials in the wastes are removed by precipitation and filtration. The filtrate contains chemicals used in the plant processes such as ammonia, hydrofluoric acids, sulfuric acids, hydrochloric acids, and various nitrates (e.g., aluminum nitrate) which have been neutralized to a pH of 9.0. Three process waste streams are routed directly to Pit 5 without undergoing a pretreatment step to precipitate out the radioactive materials. They are: Zirnlo slurry from Plant 9 which also contains high levels of copper, Heat Treat Quench Water from Plant 6 and Slag Leach Slurry from Plants 2 and 3.

Facility Contents

Since detailed records of the contents of each pit are not available, estimates were made using the available information. (Estimation methods are described in Appendix B). The estimated total number of curies in each pit are as follows: Pit 1 has 108, Pit 2 has 35, Pit 3 has 553, Pit 4 has 233, Pit 5 has 327 and Pit 6 has 178. Table 4-2 presents the estimated volumes, weights and curies of the waste contained in each pit.

The K-65 tanks are used for the storage of refinery residues that resulted from the processing of pitchblende ores. The residues or tailings contain radium-226. The inventory of material stored in the K-65 tanks is as follows:

Description	Total Waste (Lbs)	Source and Special Material Content (Lbs)
Australian Ra Cake	380,451	606
K-65 (Radium bearing waste from pitchblende ores)	19,004,675	24,121
Total	19,385,126	24,724

TABLE 4-2

Estimated Waste Content in Each Pit[a]

Pit Number	Waste Volume (c.f.)	Waste Weight (g)	U-238 (Ci) Total	U-238 (Ci) Per Gram	U-235 (Ci) Total	U-235 (Ci) Per Gram	Th-232 (Ci) Total	Th-232 (Ci) Per Gram
1	1,080,000	4.0×10^{10}	106.52	2.7×10^{-9}	1.68	4.2×10^{-11}	0.0432	1.08×10^{-12}
2	351,000	1.3×10^{10}	34.60	2.7×10^{-9}	0.55	4.2×10^{-11}	--	--
3	5,523,498[b]	2.0×10^{11}	544.78	2.7×10^{-10}	8.62	4.3×10^{-11}	0.0332	1.66×10^{-13}
4	1,436,247[c]	5.3×10^{10}	223.18	4.2×10^{-9}	3.38	6.4×10^{-11}	7.1000	1.33×10^{-10}
5	2,643,365	9.8×10^{10}	321.10	3.3×10^{-9}	4.97	5.1×10^{-11}	1.4950	1.53×10^{-11}
6	168,661	6.2×10^{9}	176.42	2.8×10^{-8}	2.49	4.0×10^{-10}	--	--

[a] Estimation methods are described in Appendix B.
[b] Volume up to 1979 (does not include waste added after 1979).
[c] Best available estimate, exceeds total capacity of the pit.

0036843
053
4751

Estimated volume of material stored in the K-65 tanks is 195,000 cubic feet. The total radioactivity is estimated to be 2×10^6 pCi/g (Ref. 12). 4751

Materials stored in one of the metal oxide tanks are the result of processing of non-pitchblende ore concentrates and contain only the trace of radium not removed in the concentration process. The inventory of materials stored in the metal oxide tank is as follows:

Description	Total Waste (Lbs)	Source and Special Material Content (Lbs)
Metallic Oxides (Residues from ore concentrates)	3,989,288	39,627

Estimated volume of material stored in metal oxide tank is 125,000 cubic feet. The total radioactivity is estimated to be 1.3×10^4 pCi/g (Ref. 12).

4.2 Processes

4.2.1 Waste Handling

Solid Wastes

Residues are transported from various producing plants on site to the chemical waste storage pits. The process plant and type of residues generated govern the type of container and mode of transportation utilized. The following are presently used: (a) drummed materials are transported on semi-flatbed trailers; (b) metal dumpsters via a dumpster vehicle; (c) bulk residues by dump trucks and dump trailers; and (d) pyrophoric metal in drums conveyed on four wheeled flatbed trailers pulled by a tow tractor or placed on skids and transported by pickup trucks.

0036844

The manner in which residues are placed in the pits depends upon the type of containers and the mode of transportation utilized. Dump trucks, dump trailers, and dumpster units are emptied directly onto the pit's edge. Drummed residues are emptied onto the pit's edge with an individual fork truck equipped with a drum rotator. The materials are then pushed into the pits by either a bulldozer or a drag line scraper.

Liquid Wastes

All of the major process areas generate liquid wastes and have individual facilities where the waste is pretreated to precipitate out the uranium. All but three of the waste streams are then pumped to the General Sump. Table 4-3 presents the maximum level of uranium allowable in the various process wastes in order for the waste to be received at the General Sump and the pH and uranium content allowed in the waste discharged to the chemical pit. The General Sump is a collection of twelve vertical tanks of various sizes, a coagulation supply tank, a lime slaker, a neutralizer and associated pumps, piping and valves established on a controlled pad. It is designed to facilitate the storage and transfer of liquid wastes within the tankage complex and the discharge therefrom, and the addition of various reagents and coagulation aids. The sump is equipped such that wastes can be transferred in all directions between the tanks within the sump. The pad is equipped with its own sump and drainage trenches to handle any leaks or accidental spills.

Eleven of the twelve tanks are carbon steel. Tank 12 (15,000 gallon) is the only stainless steel tank in the sump. This tank receives acid raffinate and functions as a preliminary neutralizing tank. Discharge from Tank 12 is pumped through a neutralizer consisting of three compartments in series, each with agitator and sensing probe and related recording-controlling instruments. Air operated valves supply lime slurry as required from the lime slurry loop.

TABLE 4-3

General Sump Specifications[a]

Receiving

Plant or Area	Maximum Level (lb U/gal)
Plant 1	0.00008
Plant 2 Raffinate	0.004
Plant 2 Filtrate	0.0004
Plant 2 Condensate	0.0004
Plant 4	0.0004
Plant 5	0.0004
Plant 6	0.00016
Plant 8	0.0004
Plant 9	0.00008
Pilot Plant Raffinate	0.002
Pilot Plant Sump Filtrate	0.0004
Tech. Lab	0.0004
Decontamination	0.0004
Pilot Plant Thorium	0.0004 lb Th/gal

Discharge to Chemical Pit

pH	8.5-10.5
Uranium	35 lb U/day[b]

Source: Reference 15

[a]Plants may obtain approval of the General Superintendent to pump streams with higher uranium levels. In emergencies, plants may obtain approval of Water Treatment Supervisor to pump such streams.

[b]General Sump will not discard streams >0.00167 lbs U/gal without receiving approval of General Superintendent.

Neutralized raffinate is routed to Tank 5 (50,000 gallons) where it is held until it is transferred either to the Recovery Plant (#8) or the Chemical Waste Pit. Tank 1 (20,000 gallons) receives high activity (Pilot Plant) streams. Tank 2 (20,000 gallons) receives clear streams and also serves as an uranium trap. Tank 3 (20,000 gallons) receives refinery (Plant 2) filtrate. Tank 4 (5,000 gallons) receives water with heavy metals, and flouride including copper containing "blue water". Tanks 6 and 7 (50,000 gallons) collect streams with low uranium value as well as water treatment reactivator blowdown containing calcium and magnesium carbonates and hydroxides. Tanks 8 and 9 (50,000 gallons) receive waters destined for river disposal. Tanks 10 and 11 (15,000 gallons) are used as settling tanks for slurried heels pumped from other General Sump Tanks. These tanks also receive neutralized raffinate when Tank 5 is full; Tank Farm water containing flouride or nitrate concentrations too high for river disposal and effluent from the ammonia stripper. (Ref. 15).

The process wastes from the various production plants and service facilities are received at the General Sump, checked for uranium content and segregated or selectively combined as required. If a waste exceeds discard specifications it is sent to the Recovery Plant or the Refinery for recovery of uranium values. If it is within the limits it is pumped through an underground pipe to Pit 5.

Three waste streams bypass the general sump and go directly to Pit 5 where the radioactive materials are allowed to settle out. The supernatent liquor in Pit 5 overflows through an effluent control tower near the western end of the pit into the Clearwell from which it is pumped to the Miami River. Figure 4-2 shows a diagram of liquid waste from origin to final disposal.

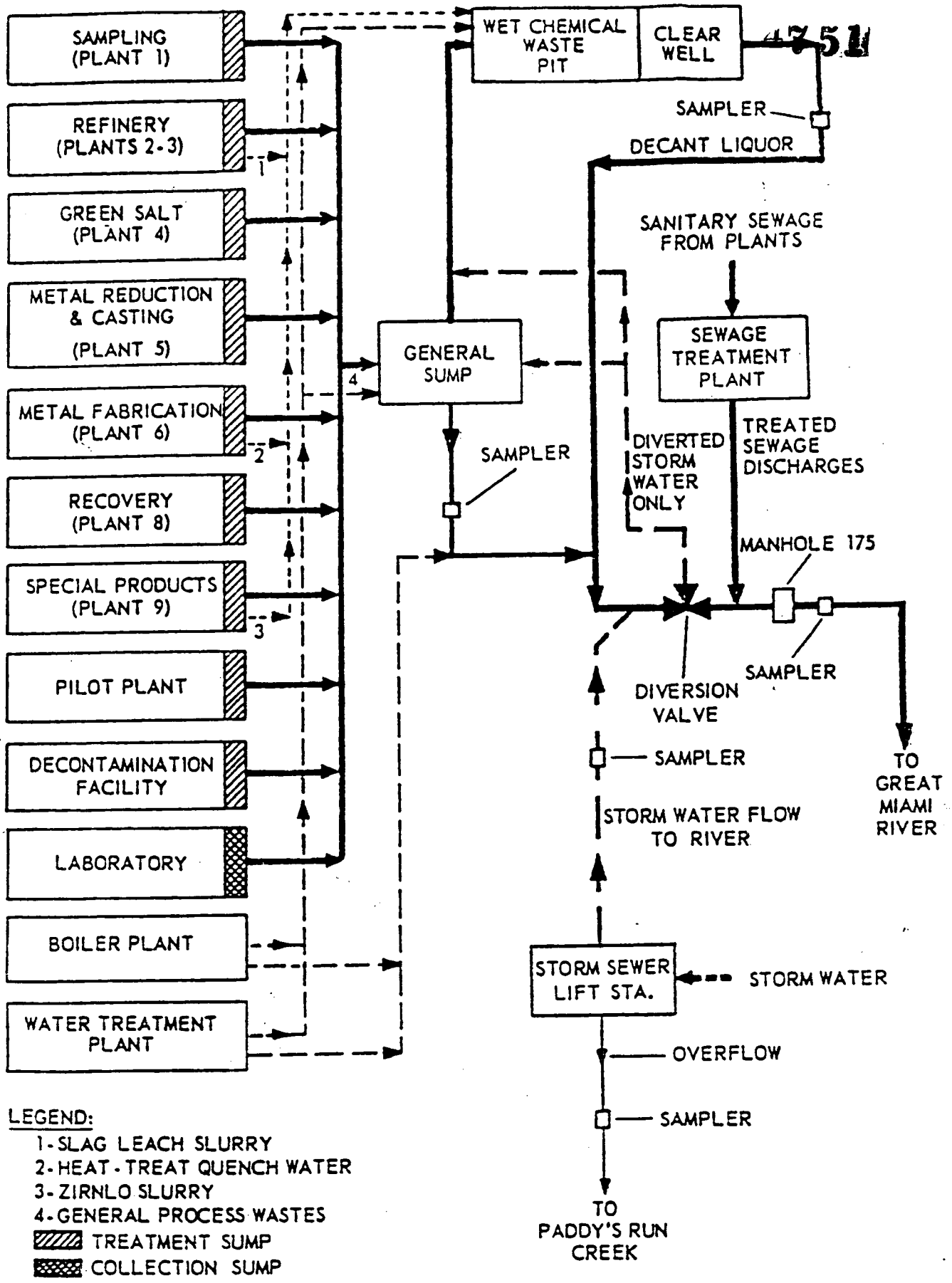


FIGURE 4-2
LIQUID WASTE FLOW DIAGRAM

0036848

058

DAMES & MOOR

REVISIONS BY DATE
FILE
DATE
BY
CHECKED BY

4.2.2 Waste Treatment

Solid Wastes

No facilities exist at the FMPC for treatment of solid radioactive wastes. Solid wastes generated are discarded without treatment to Pits 4 and 6.

Liquid Wastes

All of the major process areas have individual treatment facilities capable of pretreating the liquid wastes that are peculiar to that particular process step. Virtually all of the radioactive materials in the wastes are removed in these facilities.

Generally, these plant treatment facilities collect waste liquors, adjust the pH for precipitation of uranium, and filter the resultant slurry. Where oils are present, preliminary steps are taken to remove the oils by acidification and decantation before neutralization and precipitation. After sampling and analysis is performed to ascertain that uranium content is within pre-set allowable discard limits, the filtrate is pumped to the General Sump and the filter cake is sent to the Refinery or the Recovery Plant as a process residue (Ref. 2). In addition, barium carbonate and aluminum sulfate are used to remove Ra-226 from wastes generated at the Refinery regardless of the type of feed.

When thorium is processed in the Pilot Plant, after neutralization, the waste liquors are treated with barium carbonate and aluminum sulfate before filtration in order to reduce ^{228}Ra activity in the filtrate. Because of its higher ^{228}Ra content, raffinate from the thorium extraction process is segregated from other thorium liquid wastes and subjected to a double barium carbonate-aluminum sulfate treatment and filtration before the resultant filtrate is pumped to the General Sump (Ref. 2).

The process wastes from the various production plants and service facilities are received at the General Sump, checked for uranium or thorium content, and segregated or selectively combined as required. If certain waste exceeds discard specifications, it is neutralized, precipitated, and filtered, and the the filter cake is held for recovery of uranium or thorium. Thorium wastes, if present, are segregated, again co-precipitated with barium carbonate and aluminum sulfate to further reduce Ra-228 activity and then pumped to the Wet Chemical Storage Pit (Pit 4). All acidic wastes are adjusted for pH to obtain a maximum precipitation of radioactive material. Thereafter, these wastes are pumped to Pit 5. Other wastes are settled and decanted in successive steps prior to discharge of the supernatant liquor to the river. The settled sludges are also transferred to Pit 5 (Ref. 2)

All liquid wastes discharged to Pit 5 enter at the eastern or smaller end of the basin. The large volume of the pit, in addition to providing settling time for solids in the effluent as received, also allows time for slow interaction of effluents and additional precipitation and settling. The solids, which contain almost all of the uranium, thorium, and radioactivity remaining in the waste, settle out and remain in the pit for long-term storage. The supernatant liquor, practically solids free, overflows through an effluent control tower near the western end of the pit into a clearwell from which it is sampled and then pumped to the Miami River.

4.3 Protection and Control Systems

4.3.1 Fire Protection

No permanent fire suppression facilities are provided at the burial site other than two 30 lb Dry Chemical fire extinguishers. A 1.5 inch hose line is available on the Pit 4 pad for washing the pad and the vehicles used in transporting burial materials to the pits.

Another source of water, a well approximately 1000 feet southeast of the pits, provides water at the rate of 150 gpm (Ref. 12).

Fire prevention inspections of this site are made by the Fire Safety Inspectors on a monthly basis. The nearest manual fire alarm box is located approximately 1500 feet from the pits. The normal first alarm response to this location is one 1000 gpm pumper, one 3500 gallon tanker, one rescue vehicle, and a minimum of five fire brigade members. Turnout gear, respirators, and other protective equipment is available for fire brigade personnel (Ref. 12).

4.3.2 Criticality Control

The discarded materials are depleted so far below normal enrichment levels (<0.4%), that criticality can not occur (Ref. 13).

4.3.3 Monitoring Systems

Water

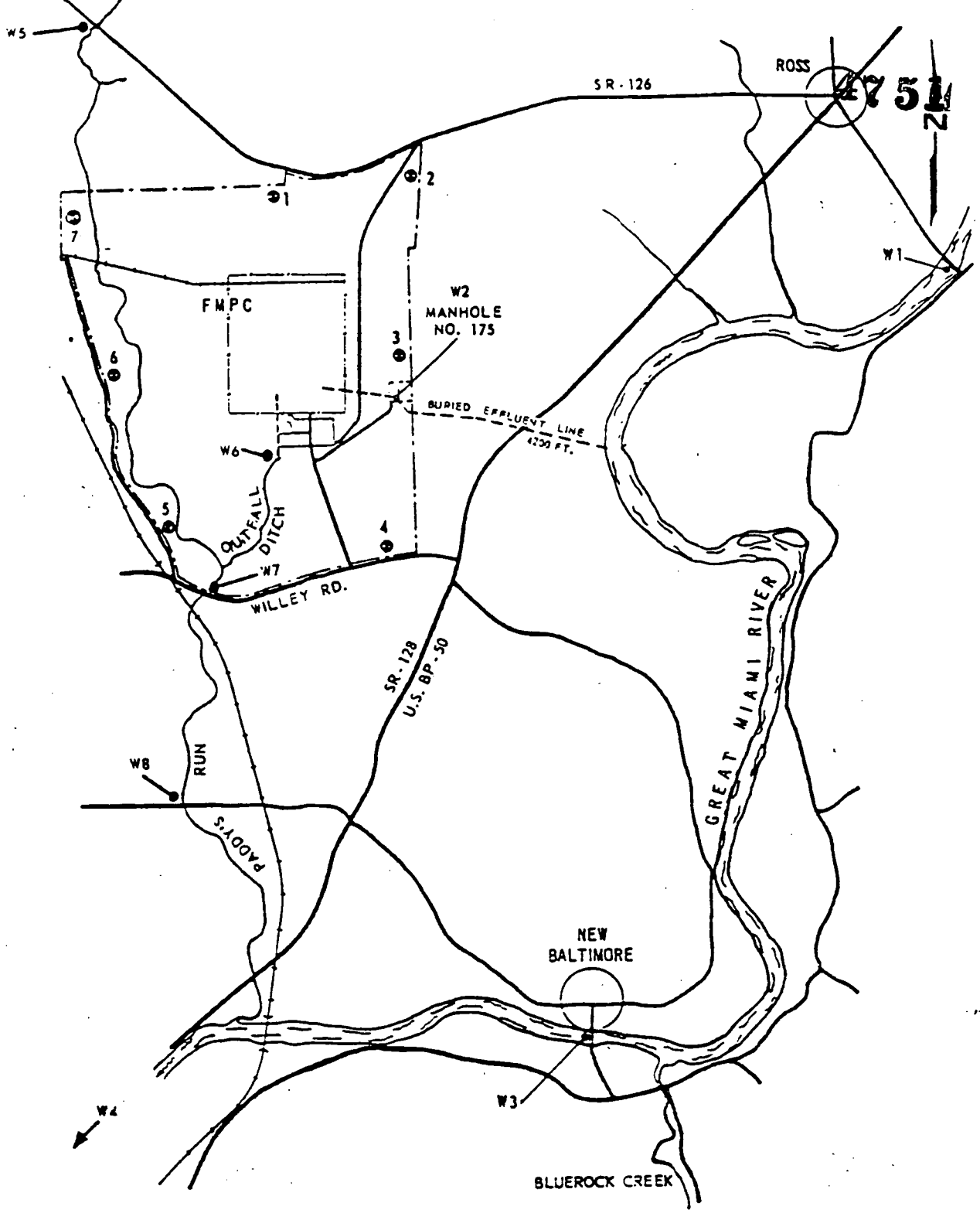
Repeated sampling and sample analysis is employed at each treatment step or junction of liquid waste streams. Samples are taken and analyzed before discharge of the treated effluent from the generating plant to the General Sump, on receipt at the General Sump, before discharge of the effluent from the General Sump and upon discharge from the Clearwell. Samples of other waste streams are similarly taken and analyzed before the wastes are sent directly to the chemical waste pit and before discharge to the Miami River. Operating procedures at each treatment step specify that no waste material is to be released before analysis is received showing the waste to be below pre-set discard limits.

Monitoring of overflows due to storm run off is done at the storm sewer lift station. The lift station is equipped with recording flowmeters and automatic proportional samplers to provide data on storm sewer system flow. One unit measures and samples the flow being pumped to the Miami River through Manhole 175. The second unit is automatically activated whenever there is an overflow to Paddy's Run Creek and provides samples and measurements of these flows. From the sample analyses and flow data, any discharge of radioactive materials through the storm sewer system can be measured.

An off-site monitoring program is conducted to determine the effect of FMPC releases on the quality of the Miami River water. Sampling locations used in implementing this program are shown in Figure 4-3. Point 1 is located upstream from the point of the FMPC discharge into the Miami River. Daily samples are taken at this point to give an indication of the quality of the water approaching the FMPC discharge. Point 2 is the continuous sampler at Manhole 175. Points 3 and 4 are located downstream from the FMPC discharge point. Grab samples are collected at Point 3 and weekly composites are analyzed; a weekly grab sample is collected at Point 4. Sample comparisons from upstream and downstream provide a means of determining the effect of the FMPC discharge on the river.

Surface water in Paddy's Run is sampled and analyzed weekly. In addition, grab samples of surface water in the waste storage pit area are obtained on a random basis and analyzed for radioactivity, NO_3 and chloride.

Test wells have been drilled around the waste pits to permit monitoring of ground water in the area. The locations of these wells are shown in Figure 4-4. The wells are sampled on a monthly basis to monitor for ground water contamination and furnish an indication of the condition of pit liners.



W4 is located at Miamitown, 4.7 miles from Paddy's Run.

⊕ BOUNDARY AIR SAMPLING STATIONS.

W1-W8 - WATER SAMPLING LOCATIONS

SCALE: 1" = 3055'

FIGURE 4-3
AIR AND WATER SAMPLING LOCATIONS

0036853

063

DAMES & MOO

REVISIONS BY DATE

FILE

DATE

CHECKED BY

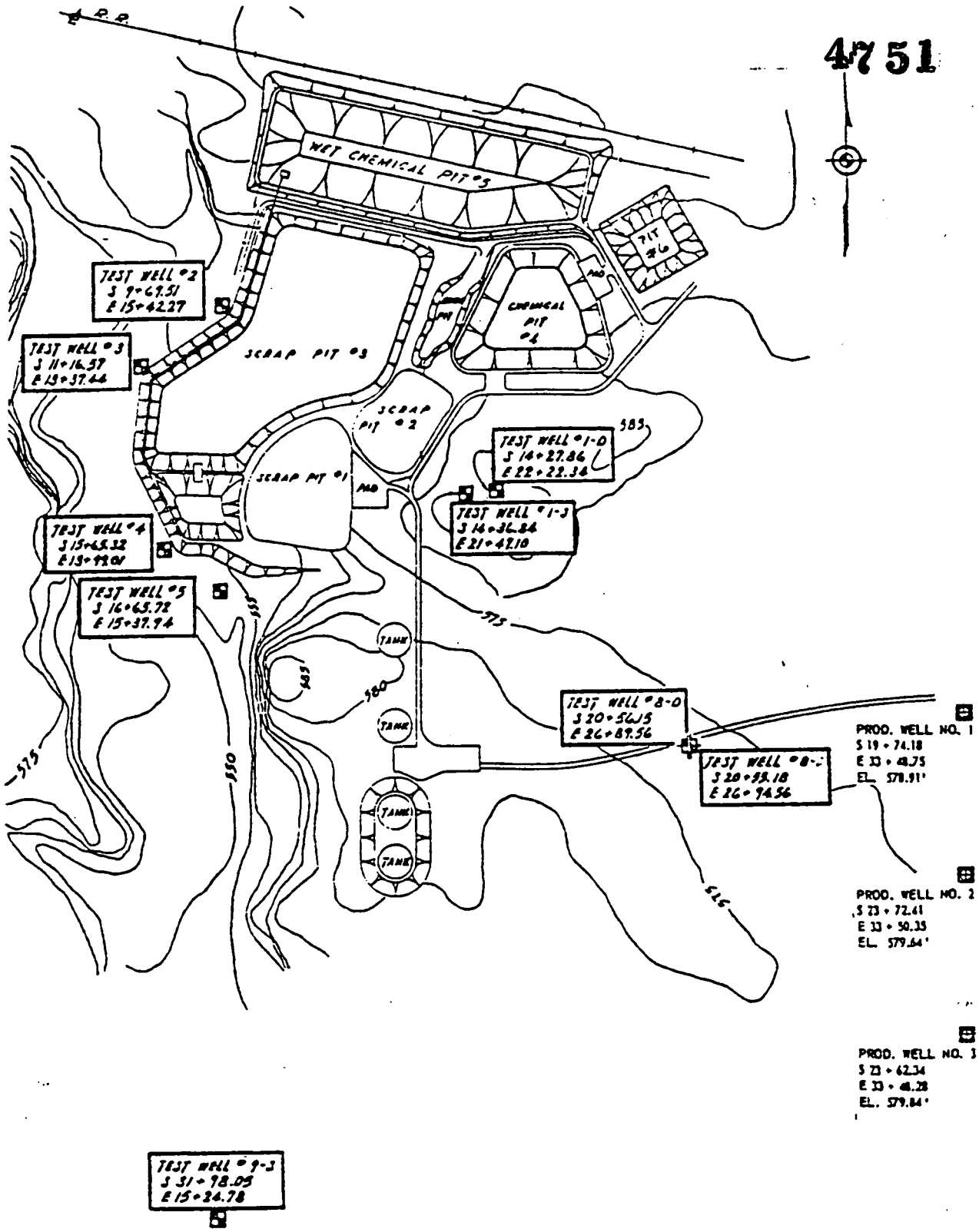


FIGURE 4-4

TEST WELL AND PRODUCTION WELL LOCATIONS

0036854

DAMES & MOOR

REVISIONS BY ____ DATE ____

FILE ____

CHECKED BY ____ DATE ____

Air

Conversion of impure uranium and thorium compounds to reactor-grade feed materials involves operations which generate radioactive dust, nuisance dusts and corrosive mists or reaction products. Ventilation and air cleaning systems such as bag collectors, electrostatic precipitators, and scrubbing towers are used to confine this air and remove contaminants. The filtered or scrubbed air is exhausted to the atmosphere. Sampling of these stack exhausts is maintained on a continuous schedule to determine the operating condition of the air cleaning systems and to measure the quantities of materials not being collected by the systems.

Samples of particulate matter in air are continuously collected at seven permanent sampling stations located on the project's outer boundary (Figure 4-3). Sampling stations 5, 6, and 7 are located on the west side of the plant. Station 6 is the closest station to the waste storage area. At each boundary station, air is drawn at a rate of about one cubic meter per minute through an 8 x 10 inch filter which is changed weekly. The collected dust is weighed and analyzed for uranium, gross alpha and gross beta. Counting is done about seven days after the end of the collection period. After these analyses are completed, the remaining solution is held to provide a long term composite for thorium analyses.

As mentioned previously, a commercial service has been used in the past two years to monitor radon air concentrations. Track etch monitoring units were placed in the boundary stations and samples were collected over periods of 4-5 months.

0036855

765

5.0 ACCIDENT ANALYSIS

5.1 Introduction

The objectives of this analysis are to: (1) examine all reasonable accident situations, (2) perform an analysis based on actual design and operating procedures of the FMPC waste storage area, (3) make conservative evaluations of accident probabilities and (4) make conservative assessments of both on-site and off-site impacts.

5.2 Approach

The approach taken in this analysis involves the following sequence of steps. First, potential accidents have been defined based on information presented in the two preceding sections concerning site and facility descriptions. Second, accident probabilities have been assigned based on a detailed examination of the site and facility descriptions and relevant information obtained from other sources. Third, estimations of on-site and off-site impacts to humans resulting from injury and from release of radioactive and toxic materials have been made using computer dispersion and dosage models. Design and operational features as well as other factors which mitigate accident impacts have also been discussed. Fourth, accidents have been classified according to the hazard they represent based on information developed in the three preceeding steps. This section summarizes the accident analyses.

The following systems have been used for classifying the accident probabilities and associated hazard. The accidents are classified in terms of high, moderate, low or extremely low probability of occurrence. Table 5-1 gives a description of each of these classes along with the probabilities associated with them. The accident hazards are classified as low, moderate, or high. Criteria used in this classification system are presented in Table 5-2.

0036856

066

TABLE 5-1

Probability Classification System

Class	Description	Probability of Occurrence
High	Event is likely to occur several times during the life of the facility	$10^{-1} > P > 1.0$
Moderate	Event is likely to occur some time during the life of the facility	$10^{-2} > P > 10^{-1}$
Low	Event is unlikely to occur during the life of the facility	$10^{-4} \geq P > 10^{-2}$
Extremely Low	Event is extremely unlikely to occur during the life of the facility	$P < 10^{-4}$

TABLE 5-2

Hazard Classification System

Class	Criteria
Low	Meets all of the following criteria: o The potential for personnel radiation exposure does not exceed the applicable limits in DOE Order 5480.1, Chapter XI, for onsite and offsite personnel. o Has no potential for a nuclear criticality. o Could not result in exposures to toxic or carcinogenic materials in excess of 1.0 threshold limit values (TLV). o Will not cause property loss in excess of $250,000. o Could result in unplanned radiological effluent release within the limits of DOE Order 5480.1, Chapter XI.
Moderate	Meets any of the following criteria: o Could result in personnel injury onsite or offsite. o Could result in onsite or offsite exposures to radiation exceeding the applicable limits provided in DOE Order 5480.1, Chapter XI. o Could result in onsite or offsite radiological release exceeding the limits provided in DOE Order 5480.1, Chapter XI. o Could result in offsite non-radiological effluents exceeding TLV's. o Could result in more than $250,000 property damage.
High	Meets any of the following criteria: o Could result in injuries to more than five (5) persons on- or offsite. o Could result in one (1) or more fatalities on- or offsite. o Could result in an unplanned nuclear criticality.

5.3 Definition of Potential Accidents and Assignment of Accident Probabilities

5.3.1 Natural Phenomena

5.3.1.1 Earthquakes

As mentioned earlier, past seismic activity in the southwestern Ohio region has been relatively minor with respect to both frequency and intensity. No earthquakes have occurred at the FMPC site. Over the 204 year period from 1776 to 1980, six were recorded in the Cincinnati area, all of low intensity (III on the Modified Mercalli scale). Only slight vibrations are felt with earthquakes of this intensity.

Earthquakes with impacts large enough to cause walls to crack are designated intensity VII or greater on the Modified Mercalli Scale. Those large enough to cause severe structural damage such as the collapse of concrete structures measure intensities VIII and IX. A study of the seismic hazard in the FMPC area reported that the return rates for earthquakes measuring intensities of VII, VIII and IX are once in 1000 years, approximately once in 100,000 years and roughly once in over a million years, respectively (Ref. 16).

5.3.1.2 Tornadoes

The probability, Ps, of a tornado striking a particular location during one year is equal to the tornado frequency (average number of tornadoes per year), $\bar{n}$, times the ratio of the area affected, a, to the total area, A, in which the tornado frequency has been determined (Ref. 17). The expression is given as:

$$Ps = \bar{n}\ (a/A) \qquad (5.1)$$

Given that the waste storage area is an estimated 37.7 acres, a; the area of Hamilton County is 264,960 acres, A, and the tornado frequency is 0.19, $\bar{n}$, (15 tornadoes occurred in Hamilton County in the 78 year period from 1900-1978) (Ref. 2); the probability of a tornado striking the waste storage area is 2.7×10^{-5} per year or about 2-3 tornadoes every 100,000 years.

5.3.1.3 Extreme Winds

Over the period 1960-1976, FMPC wind records list wind gusts in excess of 50 mph on 11 occasions and slightly in excess of 60 mph on two occasions. Possible consequences of high winds are wind induced overflowing of Pit 5 or the Clearwell and suspension of the materials in Pits 4 and 6.

It is unlikely that heavy winds would cause overflowing of Pit 5 or the Clearwell. In both of these pits, the liquid surface is at least 3 feet below the top of the pit (3 foot freeboard). Due to the short distance of wind-liquid interaction, even 60 mph winds would not result in swells which could overtop the dikes.

Significant suspension of materials in Pit 6 is also unlikely as this pit has a 15-20 foot freeboard. Also, a layer of liquid covers the waste so that initiation of saltation and particulate suspension is prevented. A similar condition exists at Pit 4 thus negating this mechanism for material dispersion.

5.3.1.4 Floods

Inundation of the waste storage area by flooding of the Great Miami River is not expected to occur as the approximate elevation of the site is 580 feet while the river has never been exceeded 555 feet at maximum flood stage in this area. Similarly, as Paddy's Run is located at an elevation of approximately 550 feet, flooding of

this stream is not expected to reach the site. It should also be noted that Paddy's Run is a small stream in which flows (ranging from 0.2-4.0 cfs) generally exists only during the period from January to May. The balance of the year it is ephemeral with occasional flash flows of a few hours duration following heavy rains. Thus, major long-term erosion causing collapse of the dikes along the western edge of the waste storage area due to flooding of Paddy's Run is unlikely to occur. In addition, there is a levee, 8-10 feet high, located between Paddy's Run and the dikes on the west side of the waste storage area. Thus flood waters would have to breech this primary levee before reaching the dikes of the pits. Erosion of these dikes is, in any event, inhibited by their thick grass coverings.

5.3.1.5 Heavy Precipitation

Since waste storage facilities at the FMPC include open pits and pits which have been covered over with loosely packed soil, heavy rainfall could potentially result in the overflow of the open pits and erosion of the covers on closed pits. Pits 4, 5, 6 and the Clearwell are open pits and Pits 1, 2 and 3 are covered. These pits are located on a raised area and are graded such that surface drainage does not flow into the pits. Therefore, water entering the pits during heavy rains would be primarily rainfall falling directly into the pit.

The maximum rainfall recorded at the Greater Cincinnati Airport was 5.2 inches in 24 hours. The maximum monthly rainfall recorded at the FMPC was 11.15 inches. Given a rainfall of 5.2 inches, the volume of water entering each of the open pits has been calculated and presented below in relation to the unfilled volume in these pits.

Pit 5 has a surface area of 156,800 square feet and a total capacity of 3,105,000 cubic feet. According to calculations discussed earlier,the used capacity of this pit is 2,643,365 cubic feet. The

unused capacity is therefore approximately 461,635 cubic feet. A rainfall of 5.2 inches would increase the volume in Pit 5 by 67,925 cubic feet which would not result in overflowing of this pit.

Pit 6 has a surface area of 32,400 square feet and a total capacity of 390,000 cubic feet. The calculated used capacity of this pit is 168,000 cubic feet. A rainfall of 5.2 inches would increase the volume in this pit by 14,040 cubic feet which would not result in overflowing of the pit.

The volume in Pit 4 is approximately 3 feet below the top of the pit. Addition of 5.2 inches of rainfall to this pit would not cause the pit to overflow.

The Clearwell is kept at a liquid level at least 3 feet below the top of the dike. Deposition of 5.2 inches of rain in this pit would not result in its overflow.

This record rainfall of 5.2 inches in 24 hours would have to persist for seven days before Pits 4, 5 and the Clearwell would overflow and 16 days before Pit 6 would overflow. It is extremely unlikely that a rainfall of this intensity would persist for seven days depositing almost a years rainfall in one week. However, if it were to occur, connections between Pits 4, 5, the Clearwell, and the General Sump enable the operator to transport wastes between Pits 4 and 5, between Pit 5 and the Clearwell, and between the Clearwell and the General Sump and out to the Miami River. Therefore, a water balance can be maintained to prevent any pit from overtopping.

5.3.1.6 Normal Precipitation

The average annual precipitation at the FMPC is 37.75 inches. Although infiltration of runoff into the pits is reduced by the

grading of pit covers, it is not completely controlled. The pit covers appear to be quite porous and poorly vegetated which may allow infiltration of rainwater. Examination of past data on nitrate concentrations in ground water suggests that infiltration of rainwater and some seepage of the water into the groundwater has occurred. However, the data are inconclusive and thus the amount of infiltration cannot be estimated.

5.3.2 Operational Accidents

5.3.2.1 Systems Failure

The waste storage area is primarily a static system involving some transport but very little manipulation of hazardous wastes. Very few pieces of equipment with parts vulnerable to failure are involved. Equipment subject to failure includes pipes, valves, and instruments used to monitor liquids during treatment and prior to discharge.

Critical valves in the waste storage system are the valves which release wastes from the tanks in the General Sump into the pipe leading to Pit 5 and the valves located on the berm of Pit 5. These valves are manually operated; therefore, it is unlikely that failure of the valves would go unnoticed and unattended.

Critical pipes in the waste storage system include two 6-inch diameter pipes which transport wastes between the General Sump and Pit 5. The length of these pipes located between the General Sump and the K-65 tank area is enclosed in a concrete trench that is covered with slabs of concrete. With the exception of a small exposed section near the gravel road between the Metal Oxide Tank area and Pit 2, the remaining length of the pipes is located underground. At Pit 5, the pipes emerge from the ground and form a T on the berm.

Standard operating procedures for waste handling in the General Sump specify that a limit of 0.00167 lbs U/gal is allowed in the liquid discharged to the Chemical Pit (Pit 5) unless special permission is obtained from the General Superintendent. For purposes of analysis, assuming that all the uranium is U-238, the maximum activity in the liquid transported through the pipes is 6.68×10^{-5} uCi/ml. Since the liquid wastes are neutralized to a pH of 9.0 at several points prior to discharge from the General Sump, the majority of the uranium is insoluble. The DOE effluent limit for insoluble uranium-238 in controlled areas is 1×10^{-3} uCi/ml. In the event that the pipes transporting liquid wastes from the General Sump to Pit 5 ruptured, the consequences would be minor since the liquids released would be well within DOE effluent limits for controlled areas (the waste storage area) and only slightly above the 4×10^{-5} uCi/ml level at which releases to uncontrolled areas is permitted. In addition, since an NLO employee is generally at the waste storage site during transfers, and in any event every 4 hours, the ruptured pipe would not be expected to remain undetected for a period of time of sufficient duration to cause a significant release of radioactive contaminants.

Instruments of importance used in connection with waste handling and subject to malfunctioning are the pH sensors located in the General Sump. Considering the procedures used in handling the wastes, it is unlikely that failure of one of these sensors would lead to the introduction of acidic liquids to Pit 5. Neutralization of the wastes within the General Sump occurs via a series of steps. Tank 12 receives the acid raffinate and functions as a preliminary neutralizing tank. Discharge from Tank 12 is pumped through a neutralizer consisting of three compartments in series. Each compartment contains a sensing probe and related recording-controlling instruments. The waste is sampled again, prior to discharge to Pit 5. Therefore, in order for acidic liquids to be released to Pit 5, a number of both system and operational failures would have to occur. In the event that several failures did occur simultaneously, release to the pit would be effectively buffered by the very substantial amount of

neutralized material in the pit. Therefore, this potential release would present no environmental hazard.

5.3.2.2 Procedure Failures

Several accidents could occur as a result of failure to implement or improper implementation of standard operating or safety procedures. These include: improper waste treatment resulting in introduction of acidic liquids to Pit 5 or discharging of low or high pH liquids from the Clearwell to the Miami River; improper valve operation resulting in overflow of Pit 5, discharge of improperly treated waste from Pit 5 to the Clearwell and uncontrolled discharge from the Clearwell to the Miami River; and improper truck operation resulting in breach of the metal oxide tanks, overturning of the trucks or driving over pit covers.

The probability of these events involves the probability of human error. In some cases the intitial error would also have to be overlooked at several other points in the waste handling process. Although the probability of the initial error may be significant, the consequences of these procedural errors are shown below to be insignificant.

As discussed in the preceding section, introduction of acidic liquids to Pit 5 or discharge to the Miami River would require the occurrence of a number of simultaneous failures to detect the improper treatment. In addition since the volume of the largest tank in the General Sump is only 0.25% of the contents of Pit 5, the tank solution would be effectively diluted and neutralized. Similarly, liquids discharged from the Clearwell to the Miami River which has an average flow of 3586 million gallons per day would be highly diluted (Ref. 7).

Improper valve operation would not result in the overflow of Pit 5 for several reasons. Excess liquids in the pit overflows into the Clearwell. In order to overflow Pit 5, over 461,635 cubic feet of

wastes would have to be pumped to the pit in a very short period of time. Considering the volume of wastes discharged from the General Sump/day and the unfilled volume in Pit 5, the pit would not fill to the point of overflow in a short enough time period that it would go unnoticed and unattended.

Discharge of improperly treated waste from Pit 5 to the Clearwell is possible, however, this would be detected by the routine sampling of the wastes prior to discharge. The liquids in the Clearwell could then be treated if necessary.

Uncontrolled discharge from the Clearwell to the Great Miami River would not have a major effect on the river since the liquids in the Clearwell are relatively free of contaminants. Prior to reaching the Clearwell, contaminants have been filtered out at the process plants and the General Sump and have settled out in Pit 5. In addition, the effect of discharges from the Clearwell to the Miami River would be minimized by dilution in the river. The consequences of this occurrence to the surrounding population is also minimized by the fact that the Miami River is not a source of drinking water.

Accidents arising out of truck operations would have localized consequences that would not effect the surrounding population and could be easily rectified. Breach of the metal oxide tank as a result of improper truck operations is not feasible since the 8 inch steel reinforced concrete walls of the metal oxide tanks would fully resist a truck impact without release of its contents. Overturning of trucks carrying wastes would require cleanup, but would not result in significant releases of contaminants to either the air or the waters. The effects of this type of accident would be limited to on-site personnel. Trained and qualified personnel are used to operate the various vehicles and equipment for movement of residues to the storage area and safety items such as goggles, respirators, gloves and normal outer protective clothing are utilized by all personnel involved in the waste storage operations (Ref. 2).

5.3.3.1 Train Derailments

A spur to the C&O Railroad runs along the north side of Pit 5 approximately 60 feet away. The distance from the fence at the site boundary to the fence around the production area is less than one mile and approximately one half mile to the edge of Pit 5. Due to the fences which require the train to stop and the short traveling distance, the potential for this train to gain speed is limited. The train travels at a speed of 5-10 mph (Ref. 3). Its low velocity precludes the development of sufficient momentum upon derailment required for the train to traverse the distance from the track to the pit area and breech the dike. Thus, the above accident scenario would not result in any release of material.

5.3.3.2 Airplane Crashes

Structures at the site are expected to withstand impacts from light aircraft typical of private planes. Impacts great enough to cause significant damage include large private aircraft and those used in commercial aviation and certain military aircraft.

Airplane crashes are known to occur most frequently within a few miles of an airport while the planes are in the process of landing or departing. Probabilities of potentially damaging aircraft impacts at power plant sites located within five miles of airports have been evaluated by the AEC. These probabilities which were based on conservative calculations were on the order of 5×10^{-7} to 1×10^{-6} per year (Ref. 17). The AEC has compiled data on aircraft movements and calculated crash probabilities as a function of distance from an airport. Only crashes resulting in a fatality were considered; however, it was assumed that accidents severe enough to create significant damage would generally involve fatal injuries. These probabilities are shown below:

Distance from Airport (miles)	Probability of a Fatal Crash per Square Mile Per Aircraft Movement
0-1	84×10^{-8}
1-2	15×10^{-8}
2-3	6.2×10^{-8}
3-4	3.8×10^{-8}
4-5	1.2×10^{-8}

As evident from the above, the probability of an airplane crash decreases with increasing distance from the airport. In the AEC analysis of the probability of an aircraft crash for various types of aircraft as a function of distance from the end of the runway, the probability of air crash declines with distance, becoming relatively constant about 10 miles out. At 9 to 10 miles away, the probability was calculated to be 1.2×10^{-9} per square mile per aircraft movement. No values were reported at greater distances.

The airports located closest to the FMPC site are the Hamilton Airport and the Greater Cincinnati Airport. Hamilton Airport is located approximately 8 miles from the site, however, it does not handle the large planes of concern in this analysis. The Greater Cincinnati Airport which handles the large commercial and private planes, is located 17 miles away from the FMPC site. Based on the probabilities arrived at in the AEC studies and the distance of the FMPC site from the Cincinnati Airport, it is reasonable to assume that the probability of a large plane crash at the site is significantly less than 1.2×10^{-9} per square mile per aircraft movement.

A total of approximately 120,000 aircraft movements occur at the Greater Cincinnati Airport per year (Ref. 18). The airport's north-south runway which handles only arrivals to the airport points in the direction of the FMPC site. This runway handles 45% of the arrivals

0036868

to the airport (Ref. 18). Therefore, approximately 27,000 planes use this runway. From the general size distribution of planes it is assumed that 75% of the planes are large enough to cause significant damage (Ref. 17). Based on the above, the number of planes, large enough to cause significant damage, potentially passing over the site on route to the Cincinnati Airport is 20,250. This is a conservative estimate since the planes do not necessarily line up with the runway at a distance of over 17 miles away. These percentages were deliberately selected to overestimate aircraft traffic to take appropriate account of large aircraft passing over the site on flights not involving arrival or departure at the Greater Cincinnati Airport.

The area occupied by the K-65 tanks is 1.79×10^{-4} square miles. Using the probability of a crash at the furthest distance (9-10 miles) for which calculations were made in the AEC study (1.2×10^{-9} per square mile per aircraft movement) the probability of a plane crash on the K-65 tanks is 4.3×10^{-9} per year. The probability of a crash into Pit 5 is 1.4×10^{-7} per year and into the waste storage area as a whole is 1.4×10^{-6} per year.

5.4 Estimation of Impacts

5.4.1 Natural Phenomena

5.4.1.1 Earthquakes

While of negligible probability, the hypothesized consequences of a Modified Mercalli Intensity VIII earthquake are analyzed below. A seismic event of this intensity will be conservatively assumed to be sufficient to cause structural damage to the domes of the K-65 tanks. In this scenario, the damage results in complete collapse of the domes onto the waste. It is also assumed that the rubble from the dome covers no more than 50% of the area, thus exposing 50% of the waste in each tank to wind erosion and the open atmosphere. This represents a long term point source of both particulates and radon.

0036869

079

To estimate the first of these source terms, the airborne suspension of particulates was calculated using the equations described in Appendix C. Using the calculated airborne suspension rate of 9.0×10^{-7} g/m^2-sec leads to a mass source term of:

$$S = 9.0 \times 10^{-7} \text{ g/m}^2\text{-sec} \times 2 \text{ tanks} \times \frac{1}{2} \pi r^2$$

where r is the internal radius of a tank (12.2 meters). Thus, the mass source term is calculated to be: 4.2×10^{-4} g/sec. Given that the major source component is Ra-226 at 3.38×10^5 pCi/g the particulate source term is equal to 142 pCi/sec.

Radon emitted from the exposed waste will also be transported off-site. The radon source term may be estimated from the following equation which is derived in Appendix D.

$$J = 10^4 \, C_{Ra} \, \rho \, E \sqrt{\lambda D} \tanh z \sqrt{\lambda / D} \qquad (5.1)$$

where:

J	= unit areal radon source (pCi/m^2-sec)
10^4	= conversion 10^4 cm^2/m^2
C_{Ra}	= waste radium content (3.38×10^5 pCi/g)
ρ	= density (1.6 gm/cm^3)
λ	= radon decay constant (2.1×10^{-6} sec^{-1})
D	= radon diffusion coefficient (1.0×10^{-2} cm^2/sec
E	= waste emanation coefficient (0.2-dimensionless)
z	= waste thickness (19.4×10^2 cm)

Substituting in the above leads to a unit source of 1.57×10^5 pCi/m^2-sec. Multiplying by the exposed area leads to a radon source of 7.3×10^2 pCi/sec.

0036870

5.4.1.2 Tornadoes

In the unlikely event that a tornado strikes the waste storage area, the radiological consequences would be negligible. Typically, tornadoes impact an area 250 yards wide and 5 miles long. Assuming as a worst case that the tornado follows a path 5 miles long by 250 yards wide after striking the pit, the immediate area of dispersion would be on the order of 1.8×10^{10} cm^2 (Ref. 19). Tornadoes have only limited ability to lift particulate matter of the type stored at the site. Assuming that 1000 Kg of waste material from the dry waste pit within the highest activity (Pit 6) which has a U-238 activity of 2.8×10^{-8} Ci/g is picked up and dispersed over this area, the radiological deposition concentration would be 1.5 pCi/cm^2. This is approximately equal to background soil concentration. Thus the increase in superficial concentration is negligible. The above analysis fails to consider factors which would tend to further reduce this concentration. Much of the suspended material will be transferred up the vortex where it will become part of the atmospheric dust load which will settle out slowly at much lower concentrations.

5.4.3 Man-Made Disasters

5.4.3.1 Airplane Crashes

The following analysis considers the worst case scenario in which the airplane crashes into one of the K-65 tanks storing wastes with high radium concentrations.

The number of curies of radon-222 available for dispersion immediately following a catastrophic accident (aircraft impact or severe earthquake) and subsequent release of material from the K-65 tanks may be estimated from the following:

- The radium content (C_t) of the stored waste material is:

$$311 \text{ mg/ton} = 3.38 \times 10^5 \text{ pCi/g}$$

0036871

081

- The radon emanation coefficient (E), i.e., fraction of total radon that escapes the waste particle matrix and is allowed to migrate) is 0.2.

- Secular equilibrium is established.

- The volume of waste in each tank is 9.7×10^4 ft^3 at a density of 100 lbs/ft^3.

The concentration of radon in the voids between the particles may be estimated from:

$$C_v = \frac{\rho E C_t}{v} \qquad (1)$$

where E and C_t are previously defined, ρ is the density (1.6 gm/cc) and v is the void fraction (the fraction of the total not occupied by solid particles). The total amount of radon (R) is calculated from:

$$R = C_v \text{ Vol } v \qquad (2)$$

where Vol is the volume of material

This reduces upon substitution to:

$$R = E\, C_t \rho \text{ Vol} \qquad (3)$$

Substituting the aforementioned values leads to a potential source of 297 Ci in each K-65 tank. However, considering the geometric configuration of the tanks and their earth embankments, only the upper portion of the stored material would be dispersed. Assuming the aircraft caused a shearing away of the top of the tank and subsequent dispersion of 10% of the material, the result would be a radon source term of 30 Ci in a 30 minute period or 1.7×10^{10} pCi/sec.

0036872

Particulates

The scenario used to estimate the "puff" release of airborne particulates from a catastrophic accident is as follows. The aircraft is assumed to shear off the top of a K-65 tank dispersing approximately 10% of the stored material along the grassy knoll surrounding the tanks. The impact and subsequent fireball resulting from the crash results in a "puff" of material being ejected into the air of which a portion is entrained by the wind and is transported offsite. The fire is extinguished within one half hour of the incident thus limiting the source term. It is also conservatively assumed that 10% of the stored waste has an aerodynamic diameter of less than 10 microns and is dispersed. Fractional release factors have been developed to estimate the quantity of nuclear material released in the course of high impact collision. Using a fractional release factor of 1.3×10^{-4} (Ref. 20) and a density of 100 lbs/ft^3 leads to a material release of:

$$9.7 \times 10^4\ ft^3 \times 100\ lb/ft^3 \times 454\ g/lb \times 10\% \times 10\% \times 1.3 \times 10^{-4} = 5.7 \times 10^3\ g$$

The Ra-226 activity of the waste material is 3.38×10^5 pCi/g. Assuming conservatively, that the composition of the "puff" is all radium and its daughters leads to a source term for Ra-226 of 1.1×10^6 pCi/sec over a 30 minute period.

Discussion

The derived source terms may be modified by a number of factors which would require more detailed data on the waste. The major assumptions of this type are:

- All the waste material is contaminated with Ra-226 to a level of 3.38×10^5 pCi/g.

- The sieve size distribution of the material is typical of uranium tailings, i.e., 10% below 10 microns.

Both these assumptions have been chosen to err on the conservative side. More information on properties of the stored material would be needed to further refine these estimates and in light of the modest risks conservatively estimated, that appears to not be required.

Table 5-3 summarizes these source terms. Table 5-4 classifies the accident probabilities and hazards according to the criteria presented in Tables 5-1 and 5-2.

TABLE 5-3

Source Term Summary

Initiating Phenomena/Accident	Source Duration	Source		
		U-238 (pCi/sec)	Ra-226 (pCi/sec)	Rn-222 (pCi/sec)
Earthquake cracking K-65 tank	30 days	-	1.42×10^{2}	7.3×10^{2}
Aircraft shearing top of K-65 tank	30 min.	-	1.1×10^{6}	1.7×10^{10}
Tornado striking Pit 6	-	Negligible	-	-

TABLE 5-4

Accident Probability and Hazard Classification

Accident	Probability Classification	Hazard Classification
Natural Phenomena		
Earthquake		
VII[a]	low	high
VIII	extremely low	high
IX	extremely low	high
Tornado	extremely low	high
Extreme winds	high	low
Floods	extremely low (zero)	low
Operational		
Systems Failure	high	low
Procedure Failure	high	low
Man-made		
Train derailment	extremely low (zero)	low
Airplane crash into:		
K-65 tank	extremely low	high
Pit 5	extremely low	high
waste storage area	extremely low	high

[a]Modified Mercalli Intensity scale.

6.0 QUALITY ASSURANCE

A quality assurance program which covers all components, systems and structures at the FMPC has been developed by NLO. Guidance on the quality assurance program is provided in a manual entitled "Quality Assurance Program Manual for NLO, Inc. FMPC", NLCO-1104 (Special) Revision 4, January 1981. All operations of the facility are required to submit a quality assurance assessment identifying critical operations. All critical operations are required to have a quality assurance plan.

Quality assurance for the air and water quality monitoring program includes various intralaboratory practices such as daily calibration of instrumentation and routine analyses of blanks, standards solutions and spiked sample aliquots. NLO also participates in the DOE quality assurance program which is conducted by the DOE Environmental Measurements Laboratory (EML). In this program, laboratories receive samples of various media for analysis. Results are reported to EML for comparison with established values (Ref. 7).

Since the materials received in the waste storage area have been neutralized, the number of active safety systems is minimal. These include pH meters, a fire alert system, storm gauges to detect storm sewer overflows and a trench sump pump. Passive systems include pit liners and covers, dikes and embankments, diversion ditches, and the fence surrounding the K-65 tanks.

7.0 CONDUCT OF OPERATIONS

Unlike most facilities where a single organization controls operations, the Waste Storage Area is affected by a number of different operations that are conducted by a variety of organizations. To the extent that these operations influence the amount of material in storage and the character of the materials, they have an impact on the probability or consequences of the initiating events identified in Chapter 5, and thus have an impact on safety at the facility.

Very few operations are actually performed at the Waste Storage Area. Most of the operations that influence it are performed elsewhere on the site. These in turn either put materials into or remove materials from the waste pits. This chapter will address operations that affect safety at the Waste Storage Area, regardless of where they are performed.

7.1 Organization

The two organizations responsible for transferring materials to and from the Waste Storage Area are the Transportation Department and the Water Treatment Plant. The Transportation Department, which is in the Procurement Division, hauls solid wastes from various generation points to Pits 4 and 6. The Water Treatment Plant which is in the Engineering Division, operates the General Sump where liquid process wastes are treated.

Transportation Department personnel involved in solid waste disposal activities include Heavy Equipment Operators, Motor Vehicle Operators, Industrial Truck Operators, and Laborers with Transportation supervision. An organizational chart of the Transportation Department showing line of authority and number of employees in each position is given in Figure 7-1. No solid waste disposal activities are conducted off-shifts. Figure 7-2 provides an organizational chart of the Water Treatment Plant personnel.

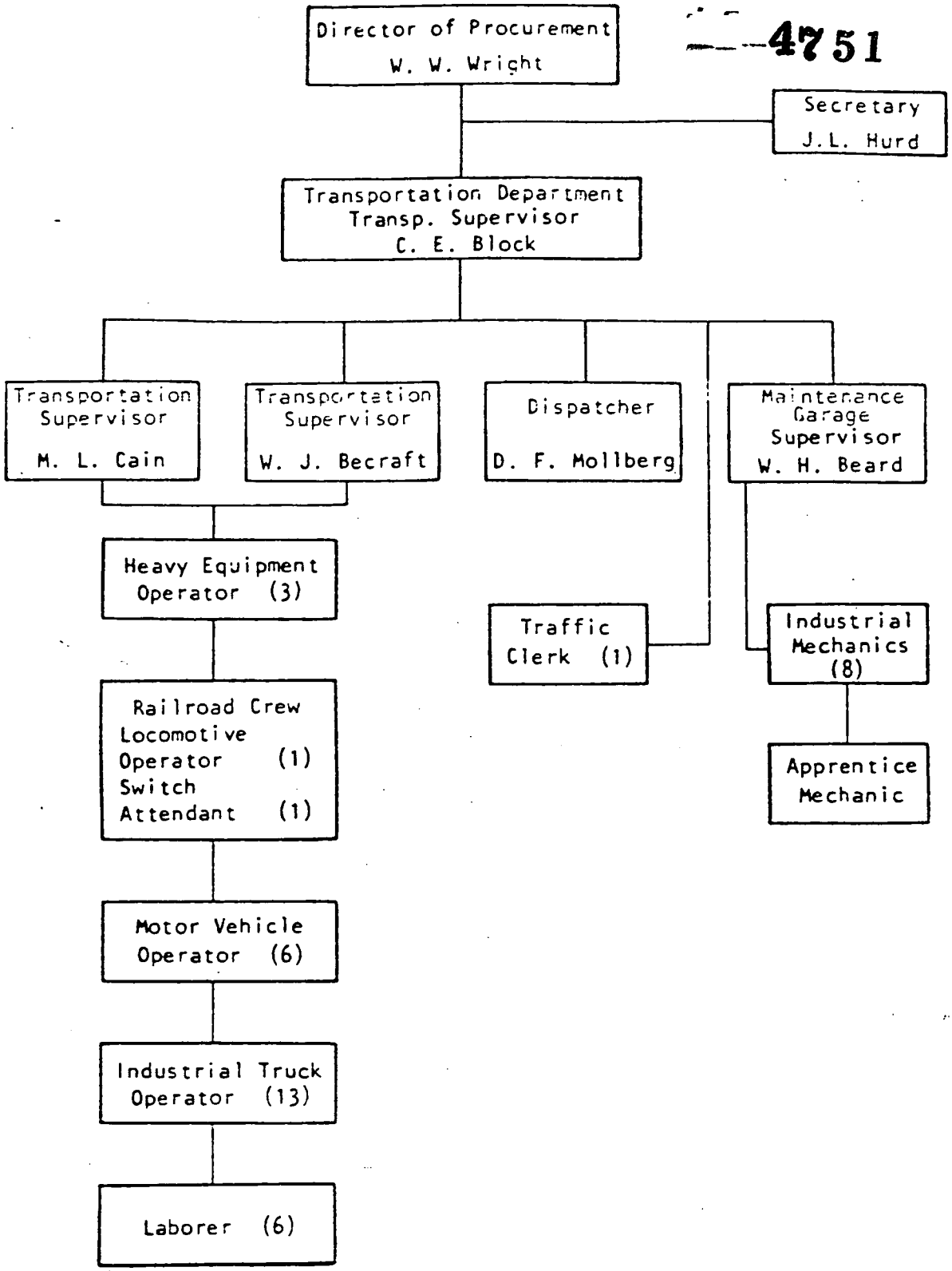


FIGURE 7-1

TRANSPORTATION DEPARTMENT ORGANIZATION

089

0036879

DAMES & MOORE

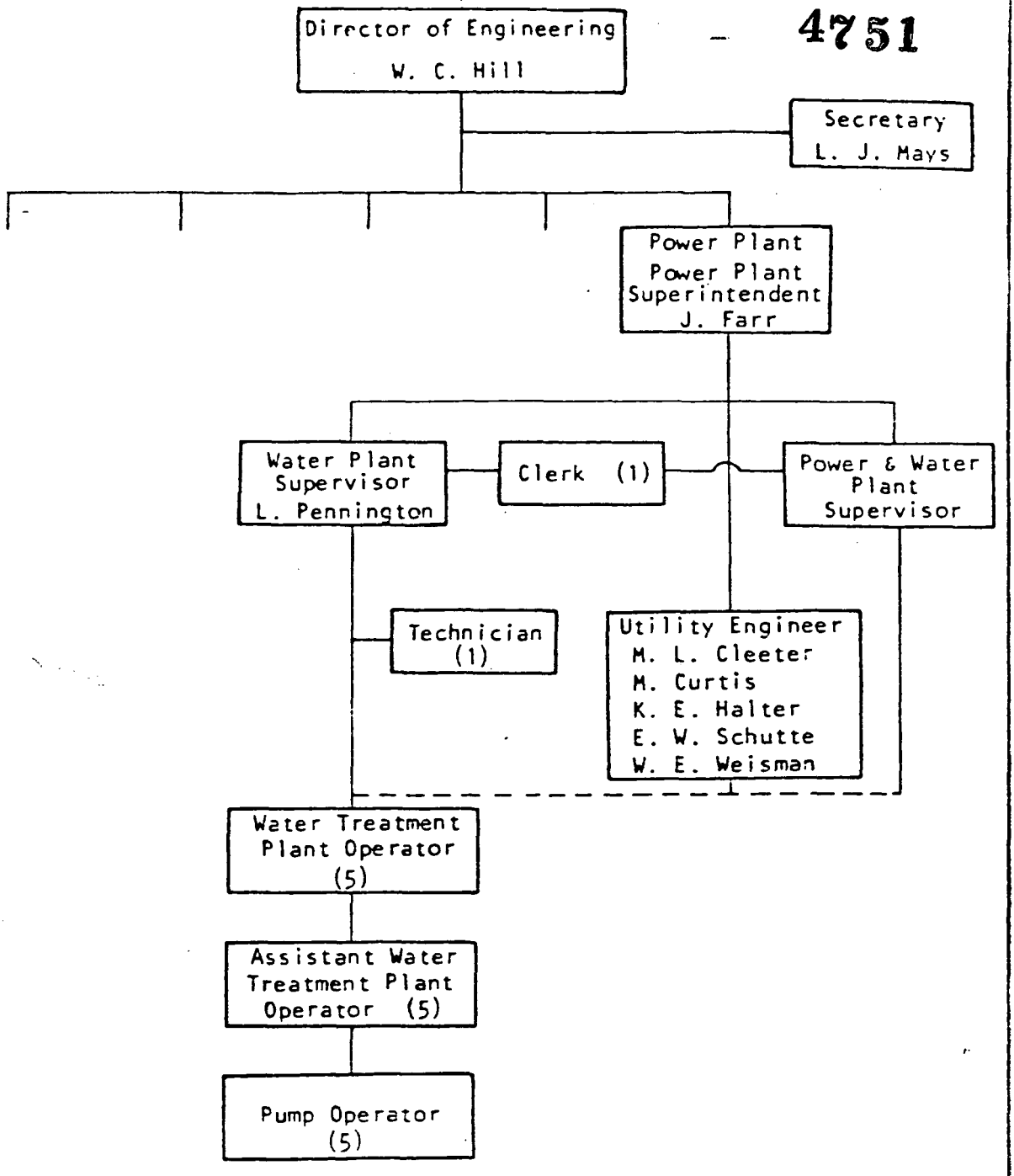


FIGURE 7-2

WATER TREATMENT PLANT ORGANIZATION

Four types of solid waste are disposed of by the Transportation Department. They are: (1) Depleted Uranium Residues - process residues of depleted uranium (0.14 - 0.52% ^{235}U) that are not suitable for remelt or that contain uranium values in amounts not economical for recovery; (2) Low Grade Thorium Residues - process residues that similarly cannot be economically processed for recovery of thorium values; (3) Contaminated Ceramics - slightly contaminated refractories from production electric furnaces discarded during repairs; and (4) General Refuse - various types of trash, generally non-combustible, which have become slightly contaminated through incidental contact with radioactive substances. The equipment used to dispose of these wastes consist of: bulldozers, plane loaders, industrial fork trucks, dump trucks, flatbed trailer, refuse units, and 30 and 55 gallon drums.

The manner by which Water Treatment Plant personnel treat liquid waste streams is determined by the origin and composition of the stream. Generally, treatment consists of adding lime to raise the pH and increase precipitation, and of adding coagulants or flocculating agents. After treatment the liquid is pumped to Pit 5 for additional settling, or offiste to the Great Miami River via manhole 175, provided that it is of sufficient quality.

Water Treatment personnel are also responsible for transferring water from Pit 5 to the Clearwell and from the Clearwell to the Great Miami River. A more complete listing of General Sump procedures is given in Reference 27, as are the criteria for offsite release of liquid wastes. Additionally, Water Treatment personnel collect samples from several places in waste streams in order to characterize the wastes. Some of these samples are analyzed at the Water Plant Laboratory, while others go to other onsite labs. The locations where samples are taken, sampling frequency, and analyses performed are listed in Reference 28.

The following procedures are used to control contamination in the waste disposal area. Surface contamination is controlled by washing vehicles used to haul wastes with water at the pit area; covering pits with topsoil and grass cover when they are filed to capacity; and grading and ditching areas surrounding the storage pits for proper runoff. Water contamination is controlled by the design of the pit area, which causes contaminated surfaces to drain into Pits 4 and 6 and the Clearwell. Water in Pits 4 and 6 is periodically pumped to Pit 5. Once there, it is treated along with liquid process wastes as described below. Airborne contamination is minimized by planning dumping so that the surface area of exposed residues is kept to a minimum, and by curtailing handling of loose powder when wind velocities are great enough to cause significant dusting. Fires are not a significant airborne contamination problem since large amounts of wood, paper or plastic are not disposed of, and uranium fires, which occur infrequently, do not generate an appreciable amount of airborne uranium. More detailed information concerning the waste disposal operations can be found in Section 19 of Reference 25 and Reference 26.

7.2 Training

In the Transportation Department, Heavy Equipment Operators, Motor Vehicle Operators, Industrial Truck Operators, and Laborers with Transportation supervision are all involved in disposing of radioactive wastes. Heavy Equipment Operators must be experienced in the operation of a variety of equipment, and receive on-the-job training in the following areas:

- Operation of all types of heavy equipment including daily inspections of equipment.
- Lifting capacities of plane loader, yard lift, and cranes.
- Communicating with hand signals.

- Operational safety standards.

Motor Vehicle Operators (MVO's) are trained initially and re-trained annually by means of classroom instruction in the following areas:

- Operator's responsibilities for vehicle and cargo.
- Onsite and offsite traffic rules and laws.
- Safe operating procedures.

All MVO's are examined initially and re-examined annually to assure proficiency in these areas. They must also pass annual driving tests.

Training for Industrial Truck Operators (ITO's) consists of classroom instruction, demonstrations, and on-the-job training in the following areas:

- Vehicle identification and operating characteristics.
- Operating techniques and procedures.

ITO's must pass a qualifying exam and performance test, and are re-evaluated at least once a year by a Transportation Supervisor.

Additionally, all Transportation Department personnel involved in the disposal of radioactive wastes are trained in the provisions of Section 19 of Reference 25. The subjects covered include:

- Types of radioactive wastes.
- Criteria and accountability of radioactive wastes.

- Equipment and containers used.
- Safety equipment to be used.
- Maintenance and contamination control of pit areas.
- Fire prevention.
- Contamination control of the storage area.
- Procedures for dumping waste materials into Pits 4 and 6.

All training is conducted by Transportation Supervisors.

Water Treatment Plant personnel receive on-the-job training in all topics covered in the Standard Operating Procedures for the Waste Plant and the General Sump. This training is conducted by the Water Plant Supervisor. The procedures most applicable to operations involving the Waste Storage Area are found in References 27 and 28. Subject areas covered during this training include:

- Operation of equipment and instruments.
- Characteristics and treatment of various waste streams.
- Criteria for transfer and/or release of wastes.
- Sampling locations and frequencies.
- Disposition of samples.

7.3 Inspection and Testing Program

Safety at the Waste Storage Area is maintained by the containment of the various wastes and their retention onsite. Failure of contain-

ment or the release of substantial contaminants in site effluents could have an impact on the environment surrounding the plant and could increase the radiation exposure of persons both on- and off-site.

It is extremely unlikely that a containment structure will fail in the absence of some initiating event, and the required initiating events are quite rare, as described in Chapter 5. Still, an informal inspection program is conducted at the Waste Storage Area. Water Plant personnel perform duties in the area during every shift, and unusual conditions should be noticed at those times. Additionally, Utility Engineers and Fire & Safety Inspectors inspect the area (monthly), and there are periodic entries by personnel from Transportation, Industrial Hygiene & Radiation, and Engineering. The area is also patrolled frequently by Security Officers.

Testing is performed on liquid wastes as described in Water Plant SOP 43-C-305 to assure that transfer/release criteria are met. Samples are taken at various points and analyzed by the Water Plant Lab, the Health and Safety Bioassay Lab, or the Technical Lab. The material pumped from the General Sump to the pits is sampled weekly and analyzed for pH, total dissolved solids (TDS), F, U, Cl, total suspended solids (TSS), NH_3, total solids, and settleable solids. The Clearwell is sampled daily, with an additional sample taken on the first day pumping occurs each week. Daily analyses are performed to determine pH, alpha activity, beta activity, U, conductivity, TDS, NO_3, F, Cl, and NH_3. Weekly analyses are performed for TSS, total chromium, haxavalent chromium, iron, nickel, and copper. A monthly composite sample is analyzed for ^{226}Ra and ^{228}Ra.

Site effluents are sampled daily at Manhole 175 with additional samples taken each Wednesday. Daily analyses are performed for pH, alpha activity, beta activity, U, conductivity, TDS, NO_3, F, Cl, TSS, Cl_2 and fecal coliform. Weekly samples are analyzed for NH_3, grease and oil, and a monthly composite is analyzed for radium and

thorium. Water pumped directly from the General Sump to the Great Miami River is sampled on the first day that pumping occurs each week. These samples are analyzed for TSS, total chromate, haxavalent chromium, iron, nickel, and copper. 4751

Occasionally, it is necessary to characterize the water in Pit 5 and water that collects in Pits 4 and 6 following a rainfall. Samples are taken as required and analyzed for pH and U.

There are also 11 test wells in and around the Waste Storage Area that are sampled monthly, with additional quarterly samples collected in January, April, August, and November. The monthly samples are analyzed for pH, conductivity, NO_3, F, U, Cl, SO_4, P-alkalinity, M-alkalinity, total hardness, Ca hardness, and Mg hardness; while the quarterly samples are analyzed for pH, alpha activity, beta activity, U, Cl, nitrate-nitrogen, SO_4, and radium.

A list of all samples taken by Water Plant personnel and the analyses performed can be found in Water Plant SOP 43-C-305. That document also identifies which laboratory performs the various analyses.

7.4 Configuration Control

Alterations to any equipment or structure at the FMPC are initiated by submission of a Job Order Request (JOR) to the Engineering Division by the requesting organization. When a JOR is received at Engineering a determination is made as to what Division should review it, and it is then circulated to those organizations. As part of this process, all JOR's are reviewed by the Health & Safety Division to insure that the proposed work will not have a deleterious effect on any safety system. This Health & Safety review is performed by the Fire & Safety Department, the Industrial Hygiene & Radiation Department, and the Nuclear Safety Department. This procedure is expalined more fully in the Engineering Division Manual (Ref. 29) as is the

0036886

procedure for insuring that drawings and associated documentation are kept up to date.

Changes in a Standard Operating Procedure (SOP) must be initiated by the organization whose operations are covered by the SOP. The request for a change is sent to the Procedures and Standards section of the Quality Control Department, which is responsible for publishing all NLO SOP's. However, before the Quality Control Department issues a revised SOP, the change must be reviewed and approved by the Health & Safety Division. This review is performed in the same manner as the review of Job Order Requests, and is intended to insure that the procedural change will not affect the safety of the operation.

7.5 Procedures

Since the Waste Storage Area is an existing facility, all procedures affecting it have already been developed and implemented. Chiefs of departments whose operations affect the Waste Storage Area are responsible for developing new procedures and assuring that procedures are kept current. The method for implementing changes in procedures is described in Section D.

7.6 Safety Review System

The Health & Safety Division at the FMPC is responsible for assuring that operations are conducted in a safe manner. Within the Health & Safety Division are professionals with experience in nuclear criticality safety, health physics, industrial hygiene, environmental quality, fire safety, and occupational safety and health. Through periodic inspections and routine surveillance, these individuals see to it that operations are conducted as safely as possible. Also, new procedures, changes in procedures, and changes in equipment must all be reviewed and approved by these individuals' departments before they can be instituted.

The performance of the various departments in the Health & Safety Division is appraised annually by representatives of Oak Ridge Operations Office. During these appraisals, action items from previous

appraisals are investigated to insure that adequate progress is being made toward their resolution. Additional areas where improvements can be made are also sought out.

4751

7.7 Emergency Planning

In the event of an emergency, the response would be in accordance with the FMPC Emergency Plan (Ref. 30). Additionally, Standard Operating Procedures 41-C-901, 20-C-901, 43-C-909, 1-C-911, 2-C-916, 2-C-911, 2-C-914, 4-C-909, 4-C-806, 4-C-802, 11-C-240, 5-C-909, 6-C-909, 9-C-909, 43-C-901, 43-C-306, 43-C-308, 10-C-105, 46-C-909, 46-C-907, and 46-C-908 set forth local actions to be taken by various site facilities for certain emergencies, such as fires and airborne releases of hazardous materials. All of the accidents identified in Section 5 for which mitigating actions would be effective are caused by initiating events that would immediately alert plant personnel (e.g., earthquake, airplane crash, etc.). Therefore emergency actions would be undertaken promptly, and should insure the safety of personnel on- and offsite.

7.8 Recordkeeping and Reporting

Radioactive materials that are transferred to the Waste Storage Area by the Transportation Department are accounted for on Form NLO-PRO-614. These forms are sent to Nuclear Materials Control, which is responsible for material accountability.

At the Water Treatment Department, all operations are recorded in a daily log, including sample analyses results (from analyses performed by Water Plant Lab), pumping operations, neutralization operations, and any other operations that affect the Waste Storage Area. Results of sample analyses that are performed at other laboratories are recorded at the laboratory that performed the analyses.

The following reports, which relate to the operation of the Waste Storage Area, are prepared and sent to the Department of Energy at the intervals listed: Feed Materials Production Center Environmental Monitoring Report, annually; NPDES Discharge Monitoring Report, quarterly; Radioactive Effluent and Discharge Data Report, annually; Radioactivity and Uranium in the Liquid Effluent, quarterly; Waste Water Quality Report, monthly; Solid Waste Information Management System (SWIMS), quarterly.

APPENDIX A

Wind Frequency and Speeds

WIND FREQ IN PERC BY STA. CLASS FOR EACH SECTOR AND TOTAL FREQUENCY

DIR	A	B	C	D	E	F
N	0.04	0.63	1.02	2.99	3.08	4.33
NNE	0.06	0.40	1.12	3.19	2.82	4.58
NE	0.05	0.47	1.14	3.22	2.23	2.78
ENE	0.02	0.49	0.86	2.47	1.68	1.61
E	0.08	0.53	0.86	3.48	2.86	1.36
ESE	0.03	0.27	0.43	2.02	1.92	0.97
SE	0.03	0.26	0.39	1.23	1.52	0.91
SSE	0.03	0.22	0.21	0.87	0.84	0.48
S	0.04	0.28	0.57	1.31	1.71	1.59
SSW	0.01	0.26	0.39	0.86	1.01	1.31
SW	0.04	0.28	0.45	0.89	1.25	1.37
WSW	0.03	0.27	0.51	0.91	1.11	1.57
W	0.03	0.38	0.63	1.22	1.77	2.28
WNW	0.01	0.24	0.38	0.79	0.91	1.48
NW	0.04	0.40	0.50	1.08	1.25	1.34
NNW	0.02	0.26	0.38	1.06	1.17	1.33

WIND SPEEDS IN M/SEC BY STA.CLASS FOR EACH DIRECTION

DIR	A	B	C	D	E	F
N	2.16	2.93	3.66	4.79	4.53	2.52
NNE	2.11	2.83	3.76	5.87	4.89	2.52
NE	2.21	3.04	3.81	5.66	5.20	2.47
ENE	1.70	2.83	4.27	5.71	5.15	2.68
E	2.16	2.83	4.07	5.87	5.41	2.93
ESE	1.96	2.63	3.86	5.82	5.46	3.19
SE	1.96	2.78	4.07	5.41	5.10	3.14
SSE	2.32	2.78	4.07	5.15	5.05	3.14
S	1.96	2.88	3.66	4.74	4.94	3.14
SSW	2.57	2.63	3.96	4.63	4.53	2.68
SW	2.37	2.63	3.35	4.32	4.48	2.68
WSW	2.32	2.99	3.66	4.27	4.32	2.83
W	2.57	2.73	3.76	4.12	4.27	2.63
WNW	2.42	2.57	3.71	4.22	4.07	2.47
NW	2.06	2.63	3.55	4.07	4.27	2.57
NNW	2.16	2.52	3.24	4.17	4.07	2.47

$

APPENDIX B

Method Used For Estimating Contents of Waste Storage Pits

Over the period 1952-1976, Pits 1-5 were used for storing waste. As of 1976, Pits 1, 2, and 3 were closed while Pits 4 and 5 remained open. Over the period 1977 to the present, Pits 4, 5 and 6 have been used for waste storage. Since records of the radioactive contents in each pit are not available, it was necessary to make estimations using the information provided by NLO. This information included the estimated:

- Volume of waste in each of Pits 1-5 as of August 1979.
- Kilograms of Uranium (normal, enriched, and depleted), U-235, U-238 and Thorium stored each year during 1952-1976.
- Total curies stored each year during 1952-1976.
- Gross volume and gross weight of waste stored each year during 1977-1981.
- Curies of U-235, U-238, Thorium, Ra-226, and Ra-228 stored each year during 1977-1981.
- Curies stored in each of Pits 4, 5 and 6 during 1977-1981.
- Kilograms of Thorium in waste storage area as of February, 1982.
- Kilograms of Thorium added to Pit 4 in 1972, 1973 and 1980.

The following methods were used. The contents of Pits 1-3 were estimated using the information given for the years 1952-1976. The

total volume of waste in each pit was obtained from the reported volume. Using the total weight of waste stored during 1952-1976, the total weight of U-235 and U-238 stored during this period and the specific activity, the average waste concentrations were determined to be 1.56×10^{-6} Ci/ft^3(U-235) and 9.863×10^{-5} Ci/ft^3(U-238). To determine how many curies of U-238 and U-235 are stored in each pit the concentrations were multiplied by the volume of waste in each pit. Since thorium is generated on an intermittent basis and since its distribution in the waste storage area is unknown it was conservatively assumed that all of the thorium generated between 1954 asnd 1957 was added to Pit 1. The values obtained for the curies of U-238, U-235 and Thorium in Pits 1-3 are in Table 4-2.

For Pits 4 and 5, an estimate of the volume of waste as of 1976 was made by subtracting from the volume reported as of 1979 an estimate of the volume of waste added between 1976 and 1979. This estimate was based on records of the waste added to the storage area between 1977 and 1981. The volume obtained for Pits 4 and 5 as of 1976 was multiplied by the previously determined concentrations to calculate the curies of U-238 and U-235 in each of these pits as of 1976.

Several pieces of information were combined to estimate the waste added to Pits 4, 5 and 6 between 1977 and 1981. It is known that approximately 100, 75 and 200 curies were added to Pits 4, 5 and 6, respectively, during this period. The proportion of U-238 and U-235 disposed of was assumed to be the same for each pit. Thus, 27% of the U-235 and U-238 went to Pit 4, 20% went to Pit 5 and 53% went to Pit 6. The curies of U-235 and U-238 per cubic foot of waste for the waste generated between 1977 and 1981 was determined from the total volume and the total curies of U-235 and U-238 generated during that time period. The calculated number of curies of U-235 in each pit was divided by the curies per cubic foot of U-235 to estimate the volume of waste added to each pit between 1977 and 1981. These volumes and

the curies of U-238 and U-235 calculated for Pits 4 and 5 during 1977 to 1981 were added to the values obtained for 1952-1976 to get the totals. Again thorium was treated separately. It was known that the thorium generated in 1972, 1973 and 1980 was stored in Pit 4. The rest of the thorium generated was divided between Pit 3 and Pit 5 depending on which pit was open.

APPENDIX C

Airborne Suspension of Particulates

Airborne suspension is in general a consequence of the saltation process. Many investigators have performed experimental and theoretical studies on airborne suspension (Ref. 21). The suspension rate (E) for particulates less than 20 um in aerodynamic diameter is given by:

$$E = 2 \times 10^{-6} (U/U_o)^2 (U/U_o - 1) [(U/U_o)^{p/3} - 1] \qquad \text{(C-1)}$$

where:

- E = suspension rate, in g/m^2-s,
- U = shear velocity (m/s),
- U_o = threshold velocity for saltation (m/s), and
- p = mass percent of particles less than 20 um in aerodynamic diameter.

The sheer velocity, U, is given by the equation:

$$U = \text{wind speed at height } (z)/[2.5 \times \ln(z/z_o)] \qquad \text{(C-2)}$$

where z_o is the height at which the windspeed is equal to zero (z_o = .01 meters). The threshold velocity for saltation U_o can be calculated using the equation:

$$U_o = A\sqrt{\frac{\sigma - \rho}{\rho} gd} \qquad \text{(C-3)}$$

where:

- σ = density of grain, 2.4 g/cm^3
- ρ = density of air, 1.2×10^{-3} cm^3 (at 20°C)
- g = gravigational constant, cm/s^2 (9.8 m/s)
- d = average diameter of the grain, 0.03 cm (300 um)
- A = dimensionless coefficient, the value of which in air for grains above 100 um in diameter was found to be about 0.1 (Ref. 22)

In this case:

$U_o = .24$ m/s

The influence of moisture in the sand on the threshold velocity for grain movement has been investigated by Belly (Ref. 23). Based on this study, the above equation can be modified to include moisture. However, in this analysis, the moisture is assumed to be insignificant.

The average wind speed in the FMPC area is 9.1 mph (4.07 m/sec). Using this wind speed measured at 1 meter above the ground surface.

$U = 0.35$ m/s

and equation (C-1) reduces to:

$$E = 1.96 \times 10^{-6} \left[(1.46)^{p/3} - 1\right] \text{ g/m}^2\text{-s}$$

In general, (p) is a coefficient around a few percent. Assuming a value of 3 percent yields:

$$E = 9.0 \times 10^{-7} \text{ g/m}^2\text{-s}$$

This value of E will be utilized in the calculation of dosage received by the surrounding population from suspension of materials released from the waste storage facilities as a result of various accidents.

APPENDIX D

Radon Flux Calculation

The assumptions for the model used to calculate the radon source term from a finite slab are as follows:

- o Radium is distributed homogeneously and isotopically throughout the material.
- o No contribution from other than the slab is included.
- o Fick's Law is applicable.

The differential equation for the model is:

$$\frac{\partial^2 C}{\partial z^2} - \frac{\lambda C}{D} + \frac{\lambda \rho E C_{Ra} C}{D} = 0 \qquad \text{(D-1)}$$

where:

C	= radon concentration at depth pCi/cm^3
λ	= radon decay constant, 2.11×10^{-6} sec^{-1}
D	= effective diffusion coefficient cm^2-sec
ρ	= bulk density of the material g/cm^3
E	= emanation coefficient i.e., that fraction of radon produced released to the void space
C_{Ra}	= radium concentration, pCi/g

The boundary conditions associated with the problem are as follows:

$$C(0) = 0 \quad ; \quad \left.\frac{\partial C}{\partial z}\right|_{z=d} = 0$$

where d is the slab thickness.

0036896

Choosing a solution of the form:

$$C(z) = \frac{\rho E}{D} C_{Ra} + A e^{rz} + B e^{-rz} \qquad \text{(D-4)}$$

where $r = \sqrt{\lambda/D}$

Leads to after some manipulation, the equation:

$$J = D\frac{\partial C}{\partial z} = - C_{Ra} E\rho\sqrt{\lambda D} \tanh(d\sqrt{\lambda/D}) \text{ in cgs units} \qquad \text{(D-5)}$$

Reversing the sign to account for the coordinate convention and converting to MKS leads to:

$$J = 10^4 C_{Ra} E\rho\sqrt{\lambda D} \tanh\left(d\sqrt{\lambda/D}\right) \qquad \text{(D-6)}$$

where J is the radon flux in units of pCi/cm^2-sec.

APPENDIX E

Dose Calculation Methods

E.0 INTRODUCTION

This section considers the calculation of radiological impacts resulting from an accidental release of radioactive materials into the atmosphere. These impacts are expressed in a two-fold manner as: doses received by an individual, and doses received by the integrated community.

Evaluation of these impacts requires the use of two computer codes. The first code (ACCIDENT) is used to model the accident conditions when a source term and short duration period prevails. This code reflects individual impacts. The second code (AIREM) is used to model the period after the initial conditions subside and until site stabilization can be achieved, e.g., long-term release. This code is used to indicate population impacts. These codes and the procedures they use are discussed in subsequent sections.

E.1 Individual Impacts

Immediately following an accident event, an amount of material (source term) will be released to the environment. This release, however, will last for only a short period of time. Under these conditions, it is assumed that the contaminant plume will move in only one direction-the direction being defined by the prevailing weather conditions at the time of the accident. Since the only members of the public who would be affected are those located immediately "downwind", this stage of the accident dictate a concern for individual impacts.

The scenario mentioned above is modeled using a standard Gaussian diffusion equation considering dispersion in the vertical and crosswind directions. The form of this equation (Ref. 20) is:

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z U} \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right] \qquad \text{(E-1)}$$

where:

- X = ground level air concentration (Ci/m^3)
- Q = source term (Ci/sec)
- h = release height (m)
- U = wind velocity (m/sec)
- σ_y = standard deviation-crosswind (m)
- σ_z = standard deviation-vertical (m)

This equation is solved repeatedly in ACCIDENT for each nuclide of concern for seven organs and at ten downwind distances. From this value (X/Q), the air concentration is obtained by direct multiplication, however, depletion due to settling and deposition is also accounted for moving outward from the site of the accident.

Further assumptions on the values of the parameters in this model were designed to produce impacts which would result under "worst" conditions. For example, a Pasquill stability class of F was assumed. This contrains the dispersion of radionuclides which leads to higher impacts. Also, a wind speed of 1 m/sec was assumed and due to the short time span decay of radionuclides was ignored.

E.2 Population Impacts

In a second scenario, material is released and is exposed to long-term weathering processes. This material is now available to be swept up by the wind and carried considerable distances. Such a process usually results in a low source term being generated for a significant period of time (i.e., until the accident site can be stabilized).

Since the time period involved with this stage is lengthy (on the order of months) the wind and weather conditions can not be considered static. Changes in wind direction, wind speed, and atmospheric stability classes must be accounted for. These conditions also indicate that no one sector of the surrounding population is more vulnerable or more safe.

The computer code used to evaluate these impacts is AIREM-a U.S. Environmental Protection Agency code used to model the atmospheric emissions of radionuclides (Ref. 24). This model uses a sector-averaged Gaussian diffusion equation similar to the one used in the previous impacts analysis, however, now a full 360 degrees is incorporated rather than a single direction. The exact form of the equation is:

$$\frac{X}{Q} = \left(\frac{2}{\pi}\right)^{1/2} \frac{f \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right] \exp\left[-\lambda t\right]}{U \sigma_z \, 2\pi \, r/n} \qquad \text{(E-2)}$$

where:

f = fractional wind frequency in a sector

λ = radionuclide decay constant (sec^{-1})

r = downwind distance (m)

n = number of wind sectors ($n = 16$)

Other variables are same as in indivudal impacts. In this code, the fractional wind frequency and average wind speeds are required as input for each of the 16 wind directions and 6 stability classes. This information was obtained from National Oceanic and Atmospheric Administration's STAR program output for the Covington, Kentucky/ Greater Cincinnati area.

AIREM calculates impacts for each radionuclide, organ, stability class, wind direction, and downwind distance. These impacts are reflective of the full range of atmospheric conditons at the site and their effect on the entire community. For this analyses with the longer time period-radioactive decay is also considered.

E.3 Dose Calculation Procedures

In this section, the term "impacts" when related to individual and populations refers to the radiological dose people receive when exposed to radioactive materials. Doses can be calculated for various organs from a variety of nuclides by multiplying the air concentration of the nuclide by a dose conversion factor. The main result of both the computer codes previously mention is calculation of the air concentrations (and simulanteously ground concentrations) resulting from a specific source term. Both the source term and the dose conversion factors are supplied to the codes as input. These parameters are discussed below.

E.3.1 Source Terms

Source terms quantify per unit time the amount of material (in this case the number of Curies) being released to the environment. In both the computer models used in this analysis, the source terms derived in Section 5 were used as input.

E.3.2 Dose Conversion Factors

Both of the computer codes described above are dose model independent, i.e., the dose conversion factors are supplied by the user. The values used in this report are the accident pathway dose conversion factors (PDCF's) developed in the Data Base for Radionuclide Waste Management (Ref. 20).

The purpose of a dose conversion factor is to relate how exposure to a particular nuclide affects human physiology. There are several uptake machanisms which can lead to human exposures. The PDCF's used in this report take into account the major uptake mechanisms at work during an accident scenario.

Under an accident scenario the time span involved is assumed to be short and the potential of exposure is likely to be quickly realized. This allows swift action to be taken to remove many uptake machanism (e.g., eating contaminated vegetables, drinking contaminated water, etc.) from consideration. The exposure mechanisms which remain deal primarily with air and soil and can be borken down as follows:

Exposure to Air

- o direct inhalation of contaminated air
- o immersion in contaminated air

Exposure to Soil

- o inhalation of air containing resuspended contmainated soil
- o immersion in air containing resuspended contaminated soil
- o standing on ground contaminated by deposition

These are the five uptake mechanisms which are considered in the accident PDCF's.

Using these PDCF's, the computer codes produce impacts in terms of dose (in mrem) received during 50 years following the initial exposure.